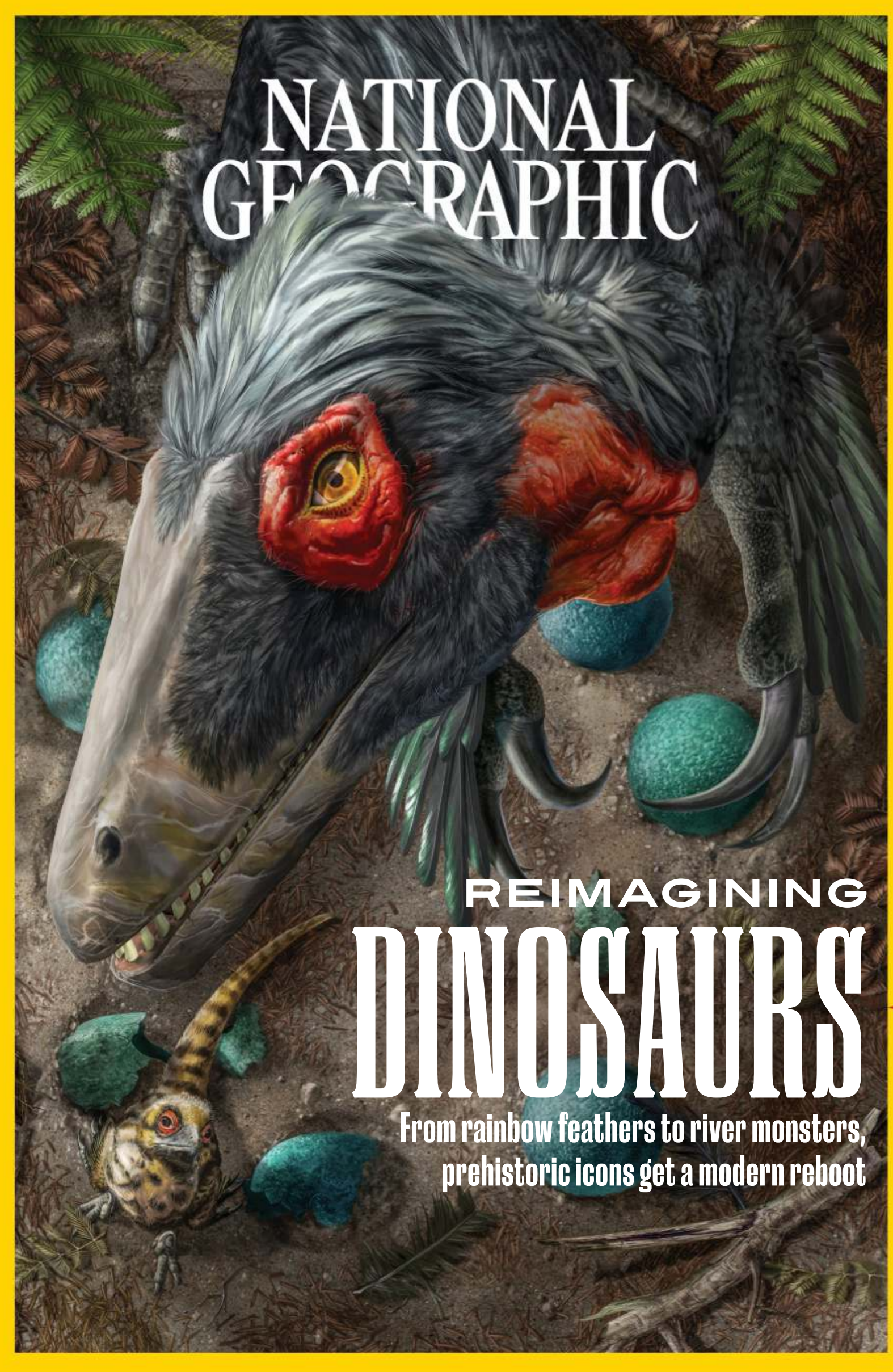
10.2020



REIMAGINING

DINOSAURS

From rainbow feathers to river monsters, prehistoric icons get a modern reboot

PURINA
Fancy Feast

THE BEST OF BOTH WORLDS

Delicate paté meets delicious gravy for a culinary experience unlike any other.

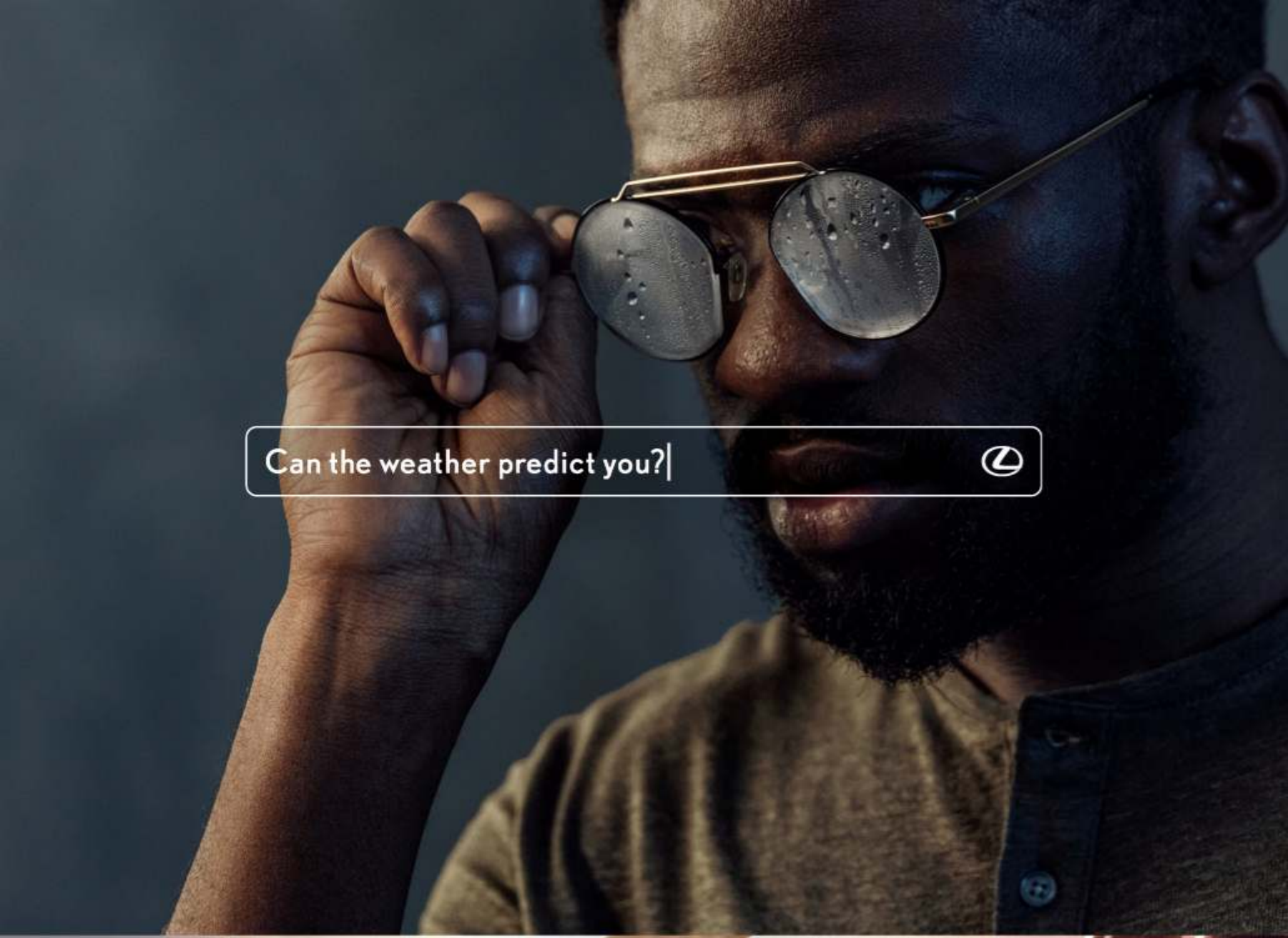
LOVE IS IN THE DETAILS®

PURINA Your Pet, Our Passion.

CONTENTS

On the Cover
A male *Deinonychus* stands over hatchlings and eggs he's brooding. Recent studies have produced many new insights into dinosaurs' looks and behaviors.
PAINTING BY DAVIDE BONADONNA

FEATURES



WE WERE CURIOUS ABOUT THAT TOO

Because you are our greatest curiosity. And we noticed the temperature of your body is constantly fluctuating from one moment to the next. So we engineered the available Climate Concierge with as many as sixteen infrared sensors to monitor your ever-changing temperature, then react with up to twenty air vents, heated and ventilated seats, and a heated steering wheel. Keeping you comfortable, automatically. And not just the driver, but also your passengers. What amazing ideas will you inspire next? Discover the answer at lexus.com/curiosity.

CLIMATE
CONCIERGE

LEXUS
EXPERIENCE AMAZING

CHILD SEX TRAFFICKING

We Hope This Story Horrifies You

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **SMITA SHARMA**

"**BEFORE THEY WERE SOLD** to the same brothel, Sayeda and Anjali were typical teenagers, growing up in similar circumstances a few hundred miles apart."

That is the understated opening of a story that I hope shocks and alarms every person who reads it, and moves readers to action. "Stolen Lives," by Yudhijit Bhattacharjee, is a revelatory investigation of a human rights tragedy: the sexual enslavement of children for profit.

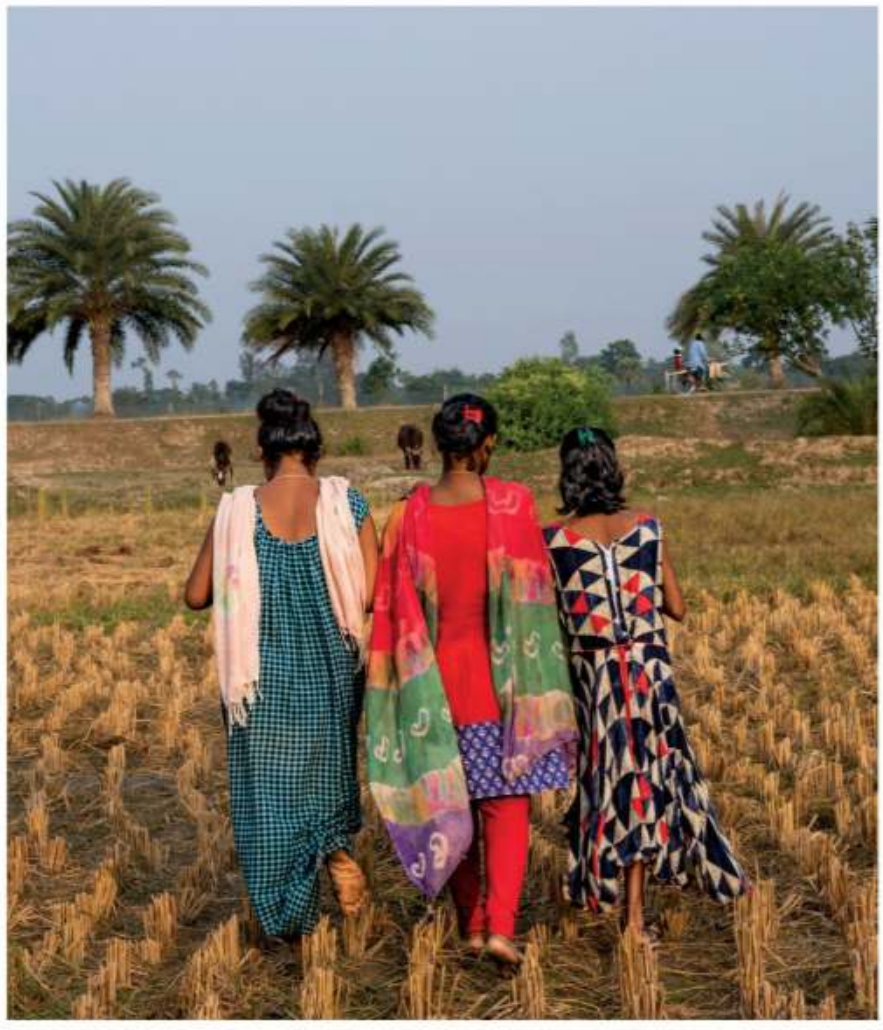
A multibillion-dollar industry, sex trafficking of minors spans the globe and ensnares millions of children—most fleeing grinding poverty, illiteracy, and an utter lack of opportunity. Most of its victims are girls.

Virtually no country is untouched by this scourge, but some parts of the world are especially hard-hit. Among them: the Indian state of West Bengal and its neighbor Bangladesh, which once were a single province known as Bengal.

"In 2017 alone, 8,178 children were reported missing from West Bengal, nearly an eighth of India's total that year. A significant number of girls among them were almost certainly sold to brothels," Bhattacharjee writes. "The picture might be worse for Bangladesh: One government estimate suggested 50,000 girls are trafficked out of the country to India, or through India, every year."

To spotlight this global tragedy, we bring you Bhattacharjee's heartbreaking account of two Bengali girls, Sayeda and Anjali. Supposed boyfriends tricked them into eloping, then trafficked them to a brothel where they were sold for sex up to 20 times a day and savagely beaten if they rebelled.

We are able to tell this story thanks to the dedication of Bhattacharjee—a *National Geographic* contributing writer who began his career covering crime in Kolkata—and Smita Sharma, a Delhi-based photographer who has documented the problem for years and whose images accompany the coverage.



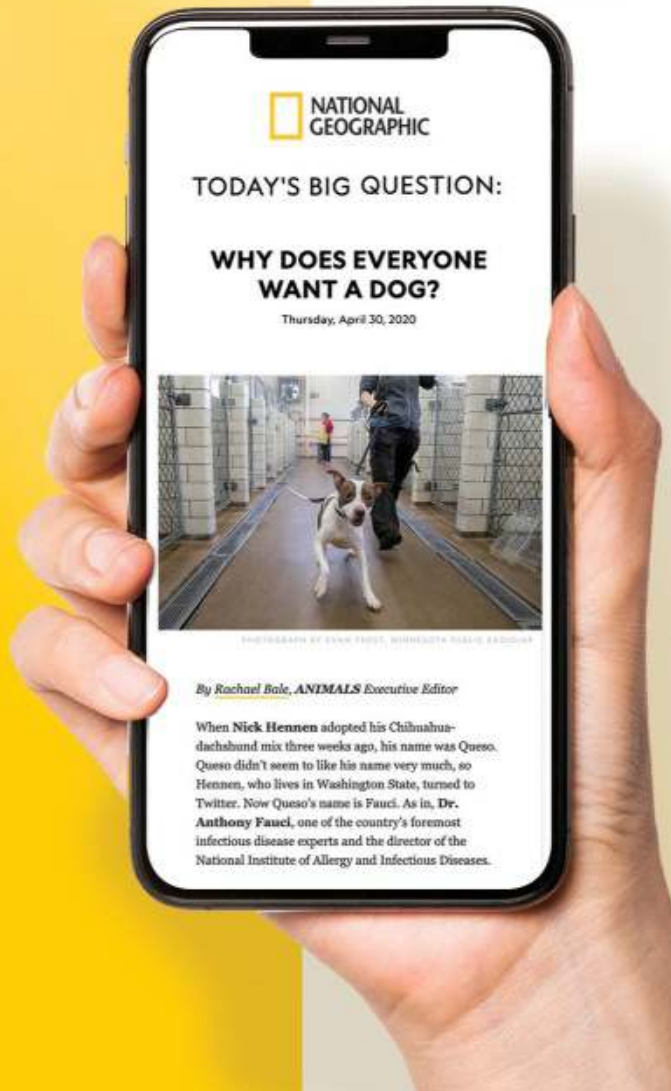
M., now 18, is flanked by her cousins on a walk through a field in India's West Bengal state. When M. was 15, a 21-year-old man she'd met drugged her, took her from her village to Delhi, beat and raped her for days, then sold her to a brothel there. She was later rescued.

In the 132 years since our founding, *National Geographic* often has called attention to human rights abuses and inhumane acts. Again and again, we are heartened by how our readers respond.

Thank you for reading *National Geographic*.

The trafficked girls in this coverage are referred to by their first initials and were photographed so they aren't identifiable. In the article "Stolen Lives," pseudonyms—Sayeda and Anjali—are used for the two featured girls. This is an exception to our policies and practice at *National Geographic*. We're masking identities to guard these young women's safety and their future, and to comply with Indian laws that protect the identity of victims of sex crimes.

START YOUR DAY WITH NATIONAL GEOGRAPHIC



Every day of the week,

learn something new as our

editors share their unique take

on trending topics in your world.

Sign up at **natgeo.com/newsletters**

PROOF

NATIONAL GEOGRAPHIC

BY **LONNAE O'NEAL**

PHOTOGRAPHS BY **JON HENRY**

MAGNIFICENT MILE, CHICAGO, ILLINOIS

EVERY MOTHER'S SON

Black mothers pose with the sons they fear losing to violence. The project is called "Stranger Fruit."

VOL. 238 NO. 4

HOUSTON, TEXAS

THERE IS A DEMAND put upon you with "Stranger Fruit." That much is clear. The photographs of mothers and sons, of Black bodies—whole and unpierced, yet still Christ-like in death—do not gently plead with viewers any more than street protesters merely invite police to change. These are Black mothers, sitting, standing, kneeling with their lifeless sons, staring straight at the camera, straight at the viewer, straight at the nation, commanding your attention, and it costs you dearly to see them. But it costs more to look away.

"What we're experiencing now is just this series of reliving these traumas as far as the African-American community," says Brooklyn-based visual artist Jon Henry. His "Stranger Fruit" exhibition is based on police killings of Black people. It draws on the song "Strange Fruit," Nina Simone's interpretation of the Billie Holiday requiem for lynched bodies "swinging in the Southern breeze, strange fruit hanging from the poplar trees." It compels you to consider the grief of families and communities left on their own and trying to move on. "It's difficult to keep living these over and over again, sort of like a perverse *Groundhog Day* where these murders just keep on happening," Henry says.

The images of real mothers and their real sons do not depict real death. Rather, they capture the constancy and ubiquity of that fear—the ringing in our Black mothers' ears that never goes away. It is knowing that the police can kill us for the smallest thing or, Henry says, "for absolutely nothing."

The mothers are seen with their sons of varying ages, posed in the classic pietà, a grieving Mary holding the dead body of Christ. The photos are shot in big cities and other places where you can see a motionless Black body without visible trauma and believe that the person is dead. These places, you understand, are complicit in what you are seeing. Henry, who for 15 years worked as a sexton in Queens, says this project was inspired by Christian iconography and memories of his mother's incessant worry as he was growing up. Stepping outside always brought exhortations to her only child to be careful, to stay safe, to make it back home.

Henry began photographing for the project in 2014. He traces its origins to 2006, when New York police officers shot and killed Sean Bell on his wedding day (three later were acquitted)—and even earlier, to 1991 and the police beating of Los Angeles motorist Rodney King. In the wake of the police killing of George Floyd, who called out to his late mother as he died, Henry's images seem prescient. But that would be true any time you travel back into the gaping maw of America, which decided early that Black bodies are expendable and Black lives matter only to their mothers, which is a way of saying the same thing.

Henry emailed the images to the mothers along with a questionnaire about their thinking before and after the photos were taken and how they approach this topic of death with their sons. Some of their anonymous responses became part of the project:

I see my sons and am in awe of the men they are becoming.
I see how much I love them and am excited for their futures.
I, however, feel very worried with the broader future that is at hand.

It is the Black mothers who know America best through the bodies of the sons they hold in their arms. It is the Black mother's gaze that implicates the nation and demands that it change. ▯

This story was produced in partnership with The Undefeated, an ESPN website that explores the intersection of race, culture, and sports.

Jon Henry asked the mothers he photographed to reflect on these scenes and their sons.

"I feel sad, sad that mothers actually have to go through this … My son was able to get up and put back on his clothes. Others, not so much."

LITTLE ROCK, ARKANSAS

SOUTH SIDE, CHICAGO, ILLINOIS

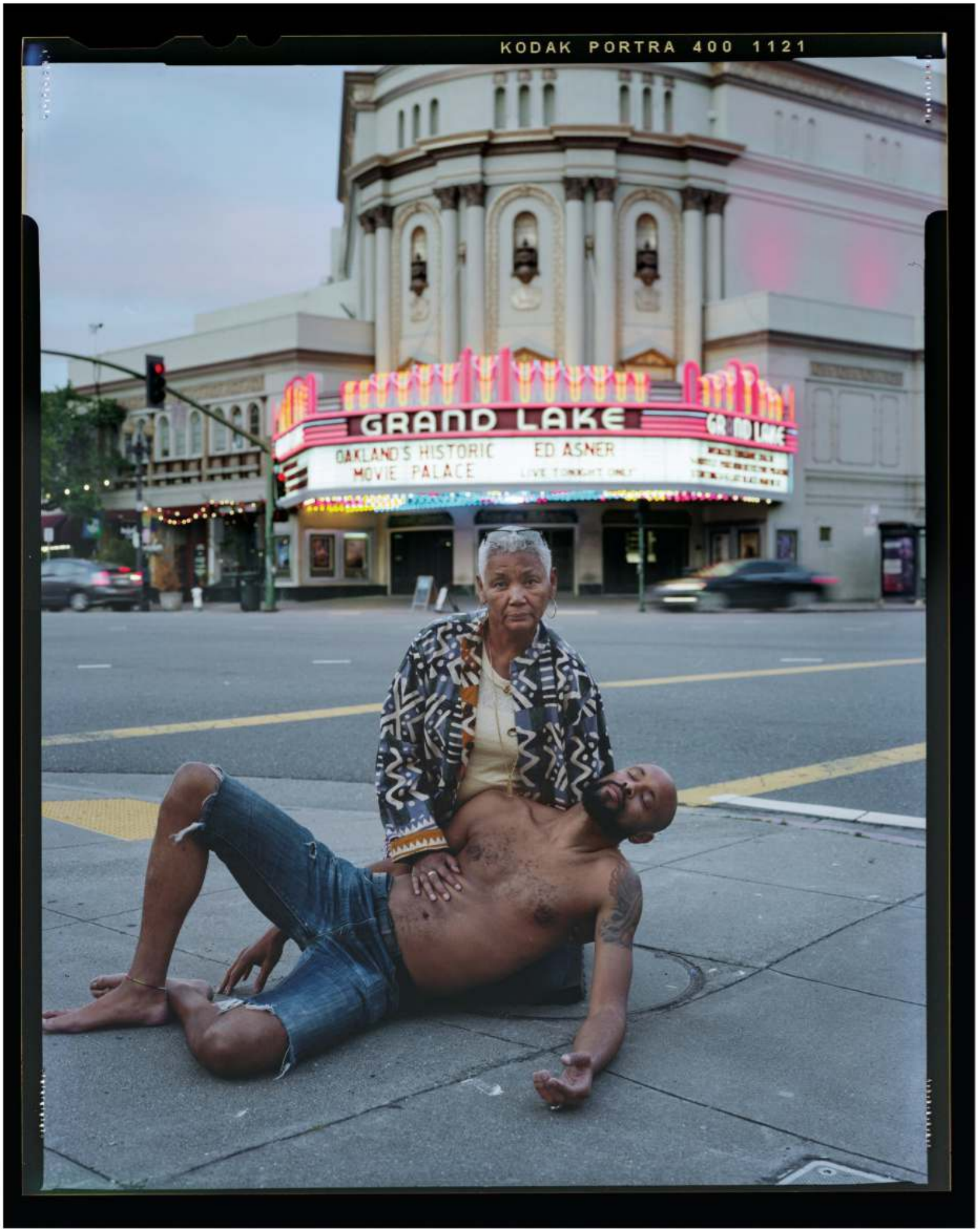
"They are still mentally frozen in that position, that sadness, that brokenness. I feel guilty to be relieved that it's just a picture because for others it's reality."

"I feel scared, I feel next. I feel like [my son's name] could be the next hashtag."

CENTRAL LOS ANGELES, CALIFORNIA

JERSEY CITY, NEW JERSEY

"As I was gradually pulled into the scene and told about the pose, it began to make me think of the daily thoughts I have about my son. I have thoughts of love, change, determination, growth, and encouragement. I also have concerns regarding his health and safety ... There needs to be immediate attention to stop the killing of Black males and suffering of mothers."



OAKLAND, CALIFORNIA

TAKE A SMART STEP TOWARD YOUR FINANCIAL FUTURE

Establishing a **charitable gift annuity** with the National Geographic Society is a simple and safe way you can receive guaranteed payments for life and save on taxes—while protecting critical animal species like this jaguar cub for generations to come.

NATIONAL GEOGRAPHIC

PHOTO: JOEL SARTORE
NATIONAL GEOGRAPHIC PHOTO ARK

SIMPLE + SAFE. SECURE YOUR FUTURE.

☐ Yes! I am interested in a charitable gift annuity. Please send me a custom illustration of my estimated payout rate, payment, and tax savings.

Gift Amount: $ _____
(Minimum gift is $10,000)

Please indicate birthdates for up to two beneficiaries:
_____/_____/_____ _____/_____/_____
(Minimum age is 60)

☐ I have some questions. Please call me.

Mail to: National Geographic Society
Office of Planned Giving
1145 17th Street, N.W.
Washington, D.C. 20036-4688

Contact: legacy@ngs.org
(800) 226-4438
natgeo.org/give/future-gifts

NAME _____

ADDRESS _____

PHONE _____ EMAIL _____

20PGAD10

ILLUMINATING THE MYSTERIES—AND WONDERS—ALL AROUND US EVERY DAY
NATIONAL GEOGRAPHIC | VOL. 238 NO. 4

Earth or Bust! A Map for Aliens

THE MAP THAT NASA SENT INTO SPACE IN 1972, OR ITS 2020 REBOOT, COULD LEAD EXTRATERRESTRIALS TO EARTH. IS THAT A GOOD THING?

BY **NADIA DRAKE** AND **SCOTT RANSOM**

A HALF CENTURY AGO astronomers designed a map that would point to Earth from anywhere in the galaxy. Then they sent it into space, reasoning that any aliens smart enough to intercept a spacecraft could decode the map and uncover its origin. Many movies and TV shows have used variations on this theme as a plot point, but we didn't borrow it from science fiction. It's reality.

Truth is, this tale has been part of my family's lore since before I was born. Growing up, I'd heard stories about the map and seen its depiction on multiple interstellar spacecraft, and several years ago, I found the original, penciled-in pathway to Earth where my parents had stashed it. (More on this later.)

That was an exciting find! Then came the buzzkill: This original map won't be good for much longer, cosmically speaking. The signposts it uses will disappear within tens of millions of years, and even if they don't, the map would point toward our home

PHOTO: ORIGINAL BY ROBERT SIMMON, NASA EARTH OBSERVATORY; REBECCA HALE, NGM STAFF

for only a fraction of the 200 to 250 million years it takes the sun and other nearby stars to spin once around the Milky Way.

Sure, the chances of aliens intercepting the map are astronomically improbable—but if that did happen, an outdated map would be useless rather than helpful. And that wasn't the goal.

WHY ON EARTH DOES THIS MAP EVEN EXIST?

It was December 1971, and NASA was getting ready to launch Pioneer 10, a spacecraft that would sweep by Jupiter and make the first reconnaissance of the solar system's biggest planet. More stunningly, though, Pioneer 10's brush by Jupiter would sling it onto an interstellar trajectory, making it the first ever human-made object destined to leave the solar system.

With a little help from his friends, the astronomer Carl Sagan decided that the craft ought to carry a greeting from humanity—a message identifying and commemorating Pioneer's makers that would be interpretable by anyone who found it. NASA agreed and gave Carl less than a month to design the message.

This is when Carl's friend, the astronomer Frank Drake, enters the story. Frank is also my dad, and among other notable accomplishments, he is credited with conducting the first scientific search for noisy aliens and with formalizing a framework for estimating the number of detectable alien civilizations in the Milky Way galaxy.

Carl asked Dad for help crafting the message while the two of them were in San Juan, Puerto Rico, for a meeting of the American Astronomical Society. Dad recalls that, in the lobby of the San Gerónimo Hilton, he and Carl quickly came up with ideas about what to include: line drawings depicting humans, a rendering of the spacecraft—and then, "in the next moment, we hit on the idea of a galactic map that would pinpoint the location of the Earth in space."

Dad designed that map, and in 1972 it flew into space aboard Pioneer 10. The next year Pioneer 11 launched, ultimately carrying the map past Saturn and now on to the stars. Then in 1977 both Voyager spacecraft left Earth carrying Dad's guide to finding our planet, which is etched onto the cover of the "golden record." The way Dad designed the map means that it points back to Earth both in space and in time, making it a galactic positioning system (a different kind of GPS) in four dimensions.

At the time, Dad and Carl didn't really worry that the aliens who found their message in a bottle might be of the more malevolent variety.

HOW THE MAP WAS MADE

Our galactic neighborhood has no obvious street signs, and crafting a map pointing to one planet among the billions (and billions) of worlds populating the Milky Way is no simple feat.

Finding Earth means finding the solar system, and the sun is rather unremarkable. There's really no way to distinguish it from the other several hundred billion stars in the galaxy, each of which is tracing its own path around the galactic center and slowly shifting in location relative to its neighbors. That stellar jostling means the constellations spangling Earth's skies won't be the same in our near future—nor do the stars align in the same recognizable configurations from anywhere other than the solar neighborhood. In fact, in about 2,000 years, Polaris will no longer be the North Star, just as it was not the polestar for ancient Egyptian, Babylonian, and Chinese sky-watchers.

So, what to do? Though normal stars with churning nuclear engines in their cores might not have distinctive fingerprints, Dad realized that pulsars—the corpses of stars that once were much larger than the sun—are potentially uniquely identifiable. Discovered in 1967, pulsars spin very rapidly, often hundreds of times per second. Using powerful radio telescopes, astronomers can measure with extreme precision how quickly pulsars rotate, meaning that each of these spinning stellar relics writes its own signature in space. Dad selected 14 pulsars that could triangulate Earth's position, and he coded information about their rotation rates into the map.

IT'S NOT YOUR TYPICAL MAP

Appropriately, Dad's pulsar map (far right, at top) looks like a fancy asterisk, a radial explosion of hatched lines that intersect at our solar system's location. Briefly, here's how his map works:

Each of the lines connect Earth to a pulsar. The hatch marks are binary numbers that reveal the pulsar's rotation rate (at the time the map was designed), and line lengths are roughly proportional to distance. Some of the pulsars parked on Dad's map—for example, the Crab and Vela—sit in the centers of beautiful nebulae created during the pulsars' violent formations. Presumably, any civilizations sharp enough to detect and snare a quiet interstellar spacecraft would know about pulsars. And by matching the rotation periods on the map with stellar signposts in the sky, aliens could find their way to Earth relatively easily.

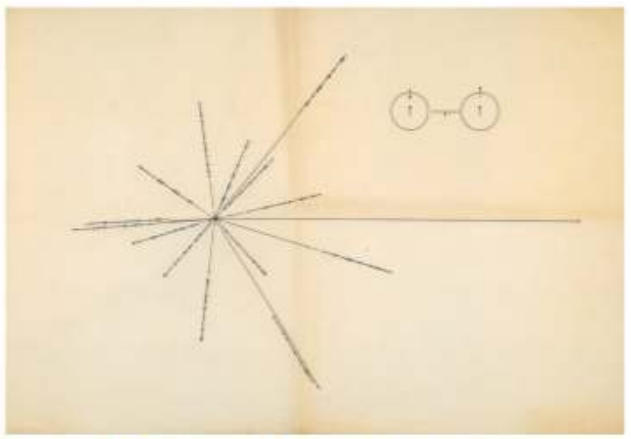
In addition, because the energy we see from pulsars comes from their spin and they slow down over time, Dad's map also points to Earth in the fourth dimension. By calculating the difference between the observed and coded rotation periods—a difference that will be apparent after thousands of years—aliens could figure out how long ago the map was made.

Perhaps somewhat surprisingly, Dad's map became lodged in the popular imagination and is now commonly found on everything from T-shirts to tattoos. I guess there's something captivating about always being able to find your way home, even in the most cosmic sense imaginable.

KEEPING IT IN THE FAMILY: A LOVE STORY

Several years ago, two significant things happened. I found the original, penciled-in pulsar map, folded away and casually tucked into a tomato box in my

PHOTOS (CLOCKWISE, FROM TOP LEFT): F. FERRARO, EUROPEAN



CLOCKWISE, FROM LEFT:

GLOBULAR CLUSTER A sparkling mass containing at least half a million stars—and some two dozen pulsars—the globular cluster known as 47 Tucanae is one of roughly 150 ancient stellar clumps orbiting the Milky Way galaxy.

PULSAR MAP The original map to Earth, designed by Frank Drake, uses 14 pulsars to point toward home. Until recently, the earliest draft of Drake's map lived in his closet, tucked into a tomato box.

CARL, DAD, AND LINDA Pictured here in 1972, Carl Sagan (at left, holding son Nick), Linda Salzman Sagan, and Frank Drake designed the plaque that Pioneers 10 and 11 would ferry to interstellar space.

PIONEER 10 Pioneer 10 is carrying a message from humanity into the stars. Etched onto a six-by-nine-inch, gold-anodized aluminum plate, the message commemorates the spacecraft's home world—and tells whoever finds it how to find us.

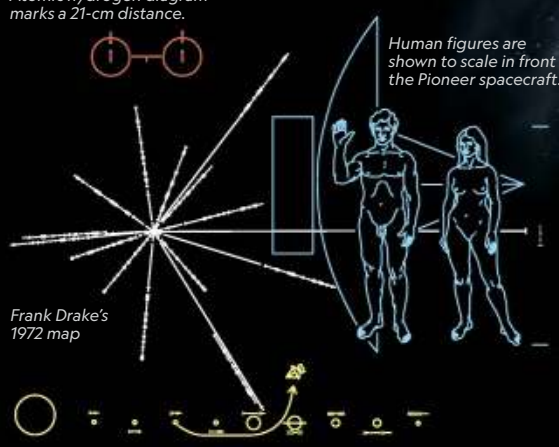
SOUTHERN OBSERVATORY; COURTESY FRANK DRAKE (MAP AND PORTRAIT); ALAMY STOCK PHOTO

Giving Aliens Our Address

To potentially help extraterrestrials locate Earth, this diagram (below) was first sent into space in 1972 attached to Pioneer 10. That spacecraft is still traveling on to the stars, but time and space are taking a toll on the cosmic coordinates it carries. The map gets increasingly unreliable as the galaxy rotates and our sun and its reference points—pulsars, the spinning cores of collapsed stars—change their relative positions. So one astronomer, Scott Ransom, is proposing a new map (far right) to overcome these weaknesses.

Atomic hydrogen diagram marks a 21-cm distance.

Human figures are shown to scale in front of the Pioneer spacecraft.

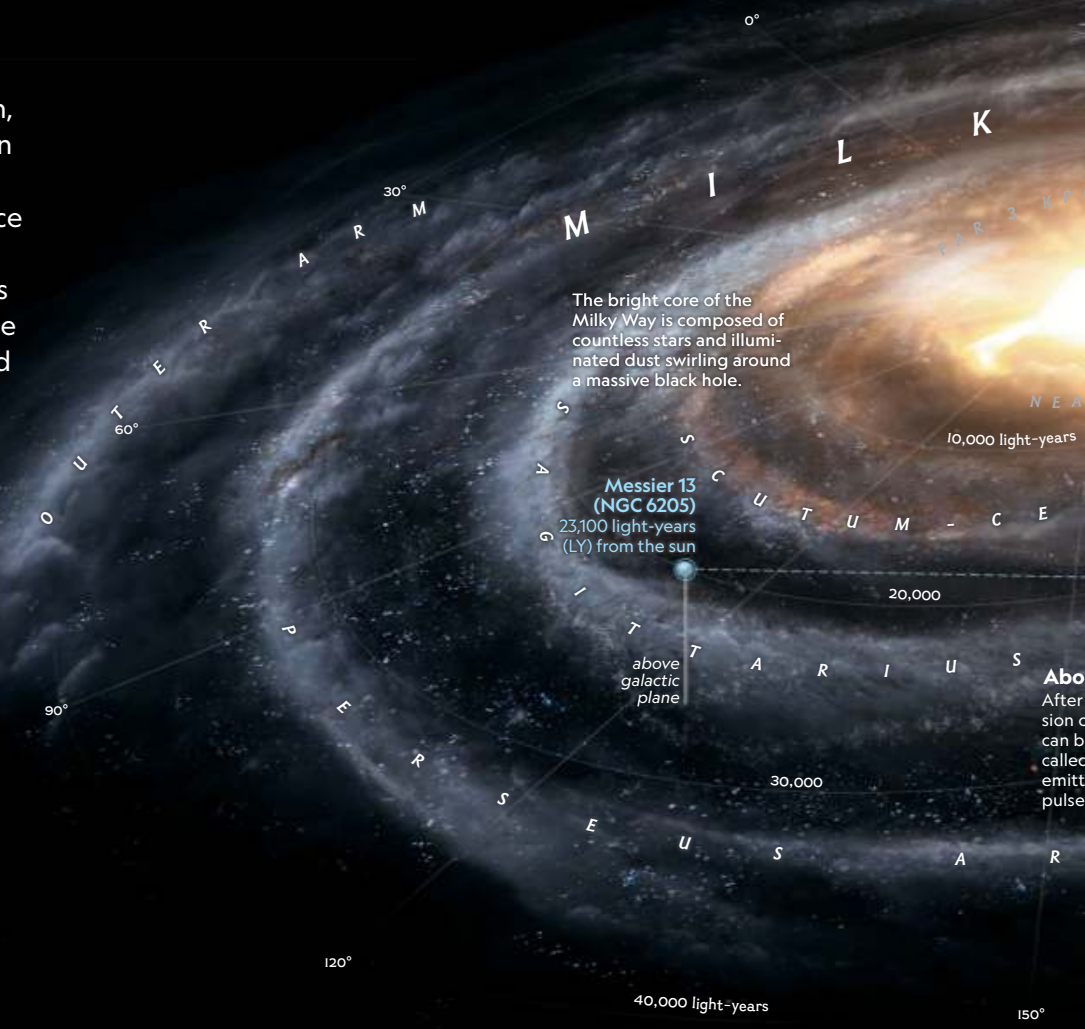


Frank Drake's 1972 map

Pioneer's trajectory is shown on this solar system diagram.

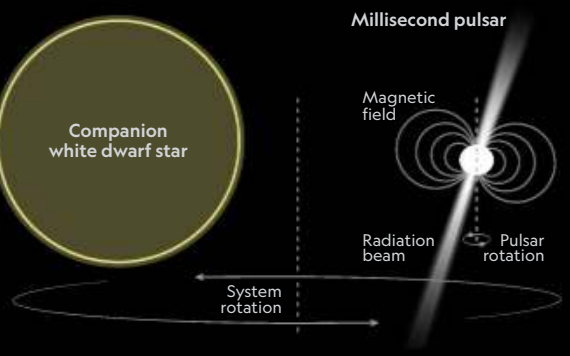
Universal ruler

Our measurements of time and distance would be unfamiliar to aliens. Hydrogen is a good universal alternative. When a hydrogen electron flips the direction of its spin, it emits a radio wave with a wavelength of about 21 centimeters, the distance light travels in just over 0.7 nanoseconds.



Stable signposts

If a small, dense pulsar is paired with another star, it siphons material and energy from its companion, accelerating the pulsar's already rapid rotation. At up to 43,000 rotations per minute, the radiation appears to pulse and acts like a beacon. This system is a reliable signpost for mapping within the Milky Way.



Galactic positioning system

Much like how the Global Positioning System (GPS) works on Earth, these galactic beacons could provide a map to the sun. By identifying these specific pulsars (at right) and how much their spins have changed, you reveal the sun's location—and Earth is right nearby.

MATTHEW W. CHWASTYK, DIANA MARQUES, NGM STAFF; SEAN MCNAUGHTON; NEW P
SOURCES: NASA GODDARD SPACE FLIGHT CENTER; NATIONAL RADIO ASTRONOMY OBS

21.10611405-cm wavelength (actual size)

Light takes 0.704024183 nanoseconds to traverse.

300°

270°

240°

210°

180°

W A Y

Y

C ARM

CORE

Terzan 5
19,200 LY

R 3 KPC ARM

N T A U R U S A R M

SAGITTARIUS ARM

below galactic plane

J1614-2230
2,100 LY

47 Tucanae (NGC 104)
14,700 LY

WE ARE HERE
SOLAR SYSTEM

S P U R

A R M

J2043+1711
4,500 LY

O R I O N

PERSEUS ARM

NGC 1851
39,500 LY

J0614-3329
2,000 LY

Direction of galactic rotation

J0218+4232
10,300 LY

M

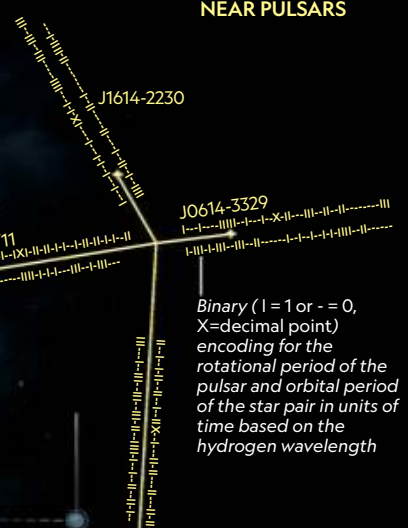
ut pulsars

a supernova—the titanic explo-
of a massive star—the star's core
ecome incredibly dense. It is
d a "pulsar" if it's set spinning,
ing radio waves that appear to
on and off like a lighthouse.

The new map

These new coordinates might more accurately guide extraterrestrial life to Earth for the next billion years or so. The map encodes how quickly rapidly spinning pulsars rotate (rotational periods) and how quickly star-pulsar systems revolve around each other (orbital periods).

NEAR PULSARS



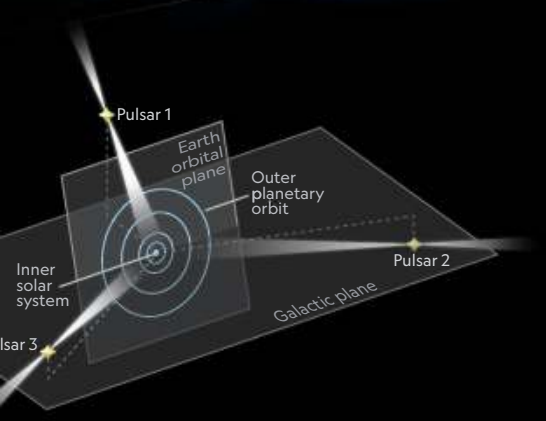
Binary (I = 1 or - = 0, X=decimal point*) encoding for the rotational period of the pulsar and orbital period of the star pair in units of time based on the hydrogen wavelength*

Our sun is similar to many other stars in the galaxy. To aid in finding it, the new map provides two scales of reference points—one up close (above) and one distant (below).

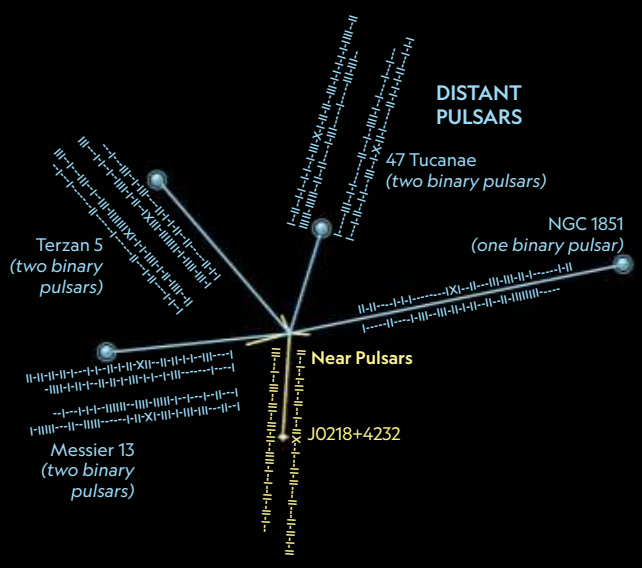
Millisecond pulsar (pulsar with a rotational period measured in fractions of a second)

Globular cluster containing millisecond pulsar

Globular clusters are dense groups of hundreds of thousands of ancient stars that orbit our galaxy. Their incredible stellar density leads to collisions and interactions over billions of years, which can produce new millisecond pulsar systems.



DISTANT PULSARS



ULSAR MAP: SCOTT RANSOM; MILKY WAY: ANTOINE COLLIGNON
SERVATORY; HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

parents' closet. And I linked up with a rock climber named Scott Ransom, one of the world's more prolific pulsar astronomers.

Scott had been thinking about the Voyagers, the "golden record," and the pulsar map since he was a 10-year-old in Mansfield, Ohio, watching Carl's *Cosmos* television show. Some years and an astronomy Ph.D. later, he realized that Dad's map has a near-future expiration date. Its Achilles' heel is the same property that lets it pinpoint Earth in time: Pulsars slow down, and the ones Dad had chosen (from the few known at the time) would fade and disappear within several million years, give or take a few millennia.

Coincidentally, Scott had set out to make a new, more precise, and longer-lived pulsar map even before we moved in together and portmanteau'd ourselves into the Dranksomes. Now I write the words that tell our stories, and Scott does the important cartographic stuff such as choosing pulsars and deriving their binary codes. He occasionally drafts some text passages, but you'll never catch me committing academic acts of astronomy.

A NEWER, BETTER MAP TO EARTH

Scott's new map is a GPS for the ages. It navigates to Earth using pulsars both inside and outside the Milky Way, with a twist.

Instead of the more ordinary pulsars Dad selected, the new map employs millisecond pulsars that spin faster, last longer, and have also-dead orbital companions. These binary pulsars afford a second set of identifiers: the orbital period of the system, which does not change over billions of years. And, crucially, millisecond pulsars age much more slowly than the ones in Dad's map, meaning that it takes thousands of times longer for their spins to become unrecognizable.

In addition, Scott included another layer of signposts: pulsars in globular clusters orbiting the Milky Way. Ancient clumps of stars that predate the Milky Way, globular clusters are gorgeous and mysterious, and they are veritable millisecond pulsar factories.

By including signposts in these hard-to-miss stellar globs outside the galaxy, Scott's map allows Earth to be discoverable for billions of years, even after the Milky Way's stars have trekked around the galactic core multiple times, shuffling their positions and obliterating constellations.

And Dad, for the record, thinks that's spectacular.

HERE'S THE FUNDAMENTAL QUESTION THAT DIDN'T STOP CARL AND DAD: IS IT A GOOD IDEA TO RANDOMLY SEND OUR ADDRESS INTO THE COSMOS?

BUT FIRST, SOMEONE HAS TO READ IT

Dad's map, of course, is still out there—but chances are slim to zero that the Pioneers or Voyagers carrying it will be intercepted. Though all four spacecraft are on interstellar trajectories, space is big, and the next stellar systems on the horizon are many thousands of years away. Plus, the spacecraft are tiny and will be completely quiet within the next couple of decades, making them extremely hard to detect.

As for sending the new map: There's no Voyager-like space probe scheduled for launch anytime soon. But if this map did hitch a ride beyond our solar system, and if it got scooped up by intelligent space aliens, the map should be quite easy for them to read and follow.

That raises all sorts of questions: Would extraterrestrial beings at those distances have the means to reach Earth? If so and they head our way, what if they don't come in peace? What if they're hangry? And what if they're not vegetarians?

Here's the fundamental question that didn't stop Carl and Dad: Is it a good idea to randomly send our address into the cosmos? Today, some folks would have no reservations, given that earthly transmissions already are leaking into space and, traveling at the speed of light, are detectable by anyone with a decent radio telescope living within a hundred light-years of us. Other folks, perhaps more cautiously, would hold off on announcing our presence until we know if ETs have honorable intentions.

As for the Dranksomes: We'd gladly send out the new map to Earth, as a bid to ensure that our presence as a species would live on in some form. If that message in a bottle were finally picked up, after bobbing and drifting through the galactic ocean for millions or billions of years, someone would know that Earthlings did exist—or, with luck, still do. ▯

Bios, verbatim

From **Nadia Drake:** "I'm a contributing writer with *National Geographic* who loves getting lost in Earth's buggy, overgrown jungles (and then finding my way home)." From **Scott Ransom:** "I'm an astronomer at the National Radio Astronomy Observatory and the University of Virginia who loves pulsars, maps, codes, and Nadia."

PHOTO: SCOTT RANSOM

NEW!

Baked With Wind Energy!

OROWEAT.
ORGANIC
BREAD
22 GRAINS & SEEDS
FIBER 4g | WHOLE GRAINS 20g | PROTEIN 6g

OROWEAT.
ORGANIC
BREAD
WHITE MADE WITH WHOLE WHEAT
FIBER 3g | WHOLE GRAINS 15g | PROTEIN 4g

USDA ORGANIC

PLANT-BASED

1% FOR THE PLANET

NON GMO Project VERIFIED
nongmoproject.org

We sustainably bake the best from the Earth to bring you and your little ones the bread you deserve!

Baking with USDA Organic and Plant-based ingredients and using renewable wind energy reflect our commitment to bringing you sustainably baked breads. Learn more at Oroweat.com/Organic

DISPATCHES FROM THE FRONT LINES OF SCIENCE AND INNOVATION

A gift wrapped in tissue

With a heart's blood and cells removed, a scaffold of connective matter (left) remains. Texas Heart Institute scientist Doris Taylor supplies stem cells, oxygen, and blood to the "ghost heart"—and new heart tissue grows. Taylor's team has grown more than a hundred test hearts and expects to create hearts suitable for transplant in the near future. –PATRICIA EDMONDS

ECOSYSTEM RESTORATION

SOUNDS BOOST HEALTH OF AILING CORAL REEFS

A LIVELY SEA-CREATURE SOUNDTRACK DRAWS FISH TO REPOPULATE DAMAGED REEFS, STUDY FINDS.

HEALTHY CORAL REEFS are pretty noisy places. "The crackle of snapping shrimp and the whoops and grunts of fish combine to form a dazzling biological soundscape" that draws juvenile fish looking for a place to settle, says marine biologist Steve Simpson. When a coral reef gets degraded, inhabitants disappear and the reef becomes "ghostly quiet," he says. "But by using loudspeakers to restore this lost soundscape, we can attract young fish back again." In 2017 Simpson and an international team of scientists placed loudspeakers along Australia's Great Barrier Reef right after a mass bleaching event to see if playing the sounds of a healthy reef could entice fish to repopulate a damaged one. After six weeks, twice as many fish settled on bleached patches of reef where sound was played as on patches where no sound was played, according to the team's study, reported in *Nature Communications*. "Fish are crucial for coral reefs to function as healthy ecosystems," says marine biologist Tim Gordon, the study's lead author. "Boosting fish populations in this way could help to kick-start natural recovery processes." –ANNIE ROTH

SYMBIOSIS

Bite makes plants flower

Bumblebees force plants to flower by biting their leaves—a discovery that may help improve agriculture. When common European bumblebees and their larvae emerge in spring, pollen is all they eat. Scientists recently found that if plants aren't flowering, the bees bite them—and those incisions somehow speed the arrival of pollen-laden blooms. When scientists tried to mimic the marks, the plants bloomed earlier, but not as early as they did for bees.

–VIRGINIA MORELL

PHOTOS (FROM TOP): TEXAS HEART INSTITUTE; HARRY HARDING; HANNIER PULIDO, COURTESY DE MORAES AND MESCHER LABORATORIES

You've worked hard to plan for today – and for the future.

We'll help you maximize every dollar with expert guidance, timely notifications and personalized Insights in the U.S. Bank Mobile App.

Get started today at usbank.com/guidance.

EQUAL HOUSING LENDER

usbank

FROM THE SHARK'S PERSPECTIVE

AS CAMERA TECHNOLOGY EVOLVES, THE CRITTERCAM'S GOAL REMAINS THE SAME: TO GO WHERE HUMANS CAN'T.

PHOTOGRAPH BY **MARK THIESSEN**

THE JULY 1906 issue of *National Geographic* was devoted to candid photographs of animals—a snacking raccoon, a moose, a jumping white-tailed deer—that had triggered a device, setting off a flash and a camera shutter. This "camera trap," made by nature photographer and U.S. congressman George Shiras, helped launch a new era of remote wildlife photography.

More than a century later, National Geographic's Exploration Technology Lab engineers are still inventing ways to capture animals in nature. Modern camera traps can run for months at a time; Crittercams are light enough to affix to fish. The devices gather footage of Earth's most endangered and reclusive creatures, as well as data and insights on the animals' behavior.

A dozen years ago, National Geographic engineers hoped to show a shark's view as it cruised along the Mexican coast. They built what's believed to be the first high-definition camera placed on a shark. One attempt to attach it ended with then engineer Mike Shepard falling off a boat as the shark prowled for more of the tuna bait that lured it there. "It's not dangerous like a firefighter's job," says Shepard, who climbed back aboard unharmed. But "every once in a while you do something ridiculous like try to put a camera on a shark." —NINA STROCHLIC

This Crittercam, which was custom-built at National Geographic headquarters, is designed to be attached to the fin of a shark to capture its movement through the water.

OUR LATEST LITTERVENTIONS :
NATURAL LITTERS THAT ACTUALLY WORK!

WITH ODOR-FIGHTING PLANT EXTRACTS

WITH ODOR-ABSORBING ACTIVATED CHARCOAL

PURINA TIDY CATS

THERE'S A TIDY CATS FOR THAT ®

PURINA Your Pet, Our Passion.®

A SPECIAL REPORT ON THE PANDEMIC

NATIONAL GEOGRAPHIC | VOL. 238 NO. 4

HOW THE VIRUS HITS ANIMALS

WHILE THE HUMAN TALLY of COVID-19 cases has risen, animal cases have remained novelties. As this issue of *National Geographic* went to press, you could count the affected species on one hand: lions, tigers, domestic cats, dogs, mink. The pets contracted the virus from their owners; the big cats, likely from an asymptomatic caregiver; and the mink, likely from fur farm workers or possibly other infected animals.

The virus is zoonotic—originating with animals—but causes a fundamentally human disease, says virologist Diego Diel of Cornell University's Animal Health Diagnostic Center. If the virus that humans are spreading were a significant threat to animal health, he says, we'd know by now.

Beyond that conclusion is a sea of unknowns. There's no evidence that domesticated animals can pass the virus to humans, but there's also no widespread animal testing. "Do we test every cat and dog that has respiratory symptoms? Maybe we will be in 12 months," says microbiologist Shelley Rankin at the University of Pennsylvania School of Veterinary Medicine. "But the only reason we've done that in the past has been when there is a direct link to human health."

Only experimental in-vivo studies, Diel says, could determine how susceptible different species are to contracting, transmitting, or getting sick from this virus.

1

Tiger, a world first
In April, Nadia, a four-year-old tiger at New York's Bronx Zoo, became the first non-domesticated animal in the world reported positive for the virus. Four other tigers at the zoo later tested positive. The tigers had coughs; that and wheezing were common animal symptoms.

2

Cats' virus risk known
Cats are known to be susceptible to coronaviruses, and several pet cats in Europe, Asia, and the U.S. have tested positive for the virus. All but one belonged to people who had tested positive for COVID-19, the disease the virus causes. The other was an outdoor cat let out in an affected area.

‘THERE’S A LOT OF CONTEXT THAT’S STILL MISSING. THIS IS ALL REALLY, REALLY NEW.’

—Microbiologist Shelley Rankin, University of Pennsylvania School of Veterinary Medicine

2

3

4

5

3

Farms’ mink infected
On several fur farms in the Netherlands, Spain, and Denmark, mink tested positive for the virus that causes COVID-19. In response, hundreds of thousands of mink on affected farms were killed, and the Netherlands is shutting its mink farm industry permanently.

4

Lions weather virus
Three lions at the Bronx Zoo also tested positive. Veterinary labs at Cornell University, the University of Illinois, and a federal lab confirmed the results by testing fecal samples. All eight lions and tigers are believed to have been infected by an asymptomatic zoo worker and have recovered.

5

Dogs’ outcomes vary
In June a German shepherd, Buddy, became the first dog in the U.S. to test positive; other dogs have too. In July Buddy died, likely from lymphoma. His case raises questions about whether some animals with underlying conditions, like cancer, may be more susceptible.

PHOTOS: JOEL SARTORE, NATIONAL GEOGRAPHIC PHOTO ARK (TIGER, MINK, LION); AUSCAPE/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES (CAT); ALVAREZ/GETTY IMAGES (DOG)

KEYTRUDA IS A BREAKTHROUGH IMMUNOTHERAPY.

FOR TODAY

KEYTRUDA is a potential first treatment for **3 out of 4 patients** with advanced non–small cell lung cancer (NSCLC).

KEYTRUDA is also used to treat **more patients** with advanced lung cancer than any other immunotherapy.

FOR THE FUTURE

Ongoing clinical trials are exploring if KEYTRUDA can help treat more patients.

KEYTRUDA may be your first treatment for advanced NSCLC, either in combination with chemotherapy or used alone as a chemotherapy-free option.
Ask your doctor if KEYTRUDA is right for you.

KEYTRUDA is a prescription medicine used to treat a kind of lung cancer called non–small cell lung cancer (NSCLC).

KEYTRUDA + CHEMOTHERAPY, NONSQUAMOUS

It may be used with the chemotherapy medicines pemetrexed and a platinum as your first treatment when your lung cancer has spread (advanced NSCLC) **and** is a type called "nonsquamous" **and** your tumor does not have an abnormal "EGFR" or "ALK" gene.

KEYTRUDA + CHEMOTHERAPY, SQUAMOUS

It may be used with the chemotherapy medicines carboplatin and either paclitaxel or paclitaxel protein-bound as your first treatment when your lung cancer has spread (advanced NSCLC), **and** is a type called "squamous."

KEYTRUDA USED ALONE, PD-L1 POSITIVE

It may be used alone as your first treatment when your lung cancer has not spread outside your chest (stage III) and you cannot have surgery or chemotherapy with radiation, **or** your NSCLC has spread to other areas of your body (advanced NSCLC), **and** your tumor tests positive for "PD-L1" **and** does not have an abnormal "EGFR" or "ALK" gene.

KEYTRUDA AFTER CHEMOTHERAPY, PD-L1 POSITIVE

It may also be used alone for advanced NSCLC if you have tried chemotherapy that contains platinum and it did not work or is no longer working **and**, your tumor tests positive for "PD-L1" **and** if your tumor has an abnormal "EGFR" or "ALK" gene, you have also received an "EGFR" or "ALK" inhibitor medicine that did not work or is no longer working.

PD-L1 = programmed death ligand 1;
EGFR = epidermal growth factor receptor;
ALK = anaplastic lymphoma kinase.

IMPORTANT SAFETY INFORMATION

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen any time during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

- **Lung problems (pneumonitis).** Symptoms of pneumonitis may include shortness of breath, chest pain, or new or worse cough.
- **Intestinal problems (colitis) that can lead to tears or holes in your intestine.** Signs and symptoms of colitis may include diarrhea or more bowel movements than usual; stools that are black, tarry, sticky, or have blood or mucus; or severe stomach-area (abdomen) pain or tenderness.
- **Liver problems, including hepatitis.** Signs and symptoms of liver problems may include yellowing of your skin or the whites of your eyes, nausea or vomiting, pain on the right side of your stomach area (abdomen), dark urine, or bleeding or bruising more easily than normal.
- **Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas).** Signs and symptoms that your hormone glands are not working properly may include rapid heartbeat, weight loss or weight gain, increased sweating, feeling more hungry or thirsty, urinating more often than usual, hair loss, feeling cold, constipation, your voice gets deeper, muscle aches, feeling very weak, dizziness or fainting, or headaches that will not go away or unusual headache.
- **Kidney problems, including nephritis and kidney failure.** Signs of kidney problems may include change in the amount or color of your urine.
- **Skin problems.** Signs of skin problems may include rash, itching, blisters, peeling or skin sores, or painful sores or ulcers in your mouth or in your nose, throat, or genital area.
- **Problems in other organs.** Signs and symptoms of these problems may include changes in eyesight; severe or persistent muscle or joint pains; severe muscle weakness; low red blood cells (anemia); swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes,

Important Safety Information is continued on the next page.

keytruda.com/lung

IMPORTANT SAFETY INFORMATION *(continued)*

or eye pain (sarcoidosis); confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis); pain, numbness, tingling, or weakness in the arms or legs; bladder or bowel problems including needing to urinate more frequently, urinary incontinence, difficulty urinating, or constipation (myelitis); and shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis).

- **Infusion (IV) reactions that can sometimes be severe and life-threatening.** Signs and symptoms of infusion reactions may include chills or shaking, shortness of breath or wheezing, itching or rash, flushing, dizziness, fever, or feeling like passing out.
- **Rejection of a transplanted organ.** People who have had an organ transplant may have an increased risk of organ transplant rejection if they are treated with KEYTRUDA.
- **Complications, including graft-versus-host disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic).** These complications can be severe and can lead to death. These complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, abdominal pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA if you have severe side effects.

Before you receive KEYTRUDA, tell your doctor if you have immune system problems such as Crohn's disease, ulcerative colitis, or lupus; have had an organ transplant or plan to have or have had a bone marrow (stem cell) transplant that used donor stem cells (allogeneic); have lung or breathing problems; have liver problems; or have any other medical problems.

If you are pregnant or plan to become pregnant, tell your doctor. KEYTRUDA can harm your unborn baby. If you are able to become pregnant, your doctor will give you a pregnancy test before you start treatment.

Use effective birth control during treatment and for at least 4 months after the final dose of KEYTRUDA. Tell your doctor right away if you think you may be pregnant or you become pregnant during treatment with KEYTRUDA.

If you are breastfeeding or plan to breastfeed, tell your doctor. It is not known if KEYTRUDA passes into your breast milk. Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Common side effects of KEYTRUDA when used alone include feeling tired; pain, including pain in muscles, bones, or joints and stomach area (abdominal) pain; decreased appetite; itching; diarrhea; nausea; rash; fever; cough; shortness of breath; and constipation.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include feeling tired or weak; nausea; constipation; diarrhea; decreased appetite; rash; vomiting; cough; trouble breathing; fever; hair loss; inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs; swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina; and mouth sores.

These are not all the possible side effects of KEYTRUDA. Tell your doctor if you have any side effect that bothers you or that does not go away. For more information, ask your doctor or pharmacist.

Please read the adjacent Important Information About KEYTRUDA and discuss it with your oncologist.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

Having trouble paying for your Merck medicine?
Merck may be able to help. www.merckhelps.com

IT'S TRU.

KEYTRUDA® (pembrolizumab) Injection 100 mg

MERCK

Important Information About KEYTRUDA® (pembrolizumab) injection 100 mg. Please speak with your healthcare professional regarding KEYTRUDA (pronounced key-true-duh). Only your healthcare professional knows the specifics of your condition and how KEYTRUDA may work with your overall treatment plan. If you have any questions about KEYTRUDA, speak with your healthcare professional. **℞ONLY**

What is the most important information I should know about KEYTRUDA?

KEYTRUDA is a medicine that may treat certain cancers by working with your immune system. KEYTRUDA can cause your immune system to attack normal organs and tissues in any area of your body and can affect the way they work. These problems can sometimes become severe or life-threatening and can lead to death. These problems may happen anytime during treatment or even after your treatment has ended.

Call or see your doctor right away if you develop any symptoms of the following problems or these symptoms get worse:

Lung problems (pneumonitis). Symptoms of pneumonitis may include:

- shortness of breath
- chest pain
- new or worse cough

Intestinal problems (colitis) that can lead to tears or holes in your intestine. Signs and symptoms of colitis may include:

- diarrhea or more bowel movements than usual
- stools that are black, tarry, sticky, or have blood or mucus
- severe stomach-area (abdomen) pain or tenderness

Liver problems, including hepatitis. Signs and symptoms of liver problems may include:

- yellowing of your skin or the whites of your eyes
- nausea or vomiting
- pain on the right side of your stomach area (abdomen)
- dark urine
- bleeding or bruising more easily than normal

Hormone gland problems (especially the thyroid, pituitary, adrenal glands, and pancreas). Signs and symptoms that your hormone glands are not working properly may include:

- rapid heart beat
- weight loss or weight gain
- increased sweating
- feeling more hungry or thirsty
- urinating more often than usual
- hair loss
- feeling cold
- constipation
- your voice gets deeper
- muscle aches
- feeling very weak
- dizziness or fainting
- headaches that will not go away or unusual headache

Kidney problems, including nephritis and kidney failure. Signs of kidney problems may include:

- change in the amount or color of your urine

Skin problems. Signs of skin problems may include:

- rash
- itching
- blisters, peeling or skin sores
- painful sores or ulcers in your mouth or in your nose, throat, or genital area

Problems in other organs. Signs and symptoms of these problems may include:

- changes in eyesight
- severe or persistent muscle or joint pains
- severe muscle weakness
- low red blood cells (anemia)
- swollen lymph nodes, rash or tender lumps on skin, cough, shortness of breath, vision changes, or eye pain (sarcoidosis)
- confusion, fever, muscle weakness, balance problems, nausea, vomiting, stiff neck, memory problems, or seizures (encephalitis)
- pain, numbness, tingling, or weakness in your arms or legs, or bladder or bowel problems, including the need to urinate more often, leaking of urine, trouble urinating, or constipation (myelitis)
- shortness of breath, irregular heartbeat, feeling tired, or chest pain (myocarditis)

Infusion (IV) reactions that can sometimes be severe and life-threatening. Signs and symptoms of infusion reactions may include:

- chills or shaking
- shortness of breath or wheezing
- itching or rash
- flushing
- dizziness
- fever
- feeling like passing out

Rejection of a transplanted organ. People who have had an organ transplant may have an increased risk of organ transplant rejection. Your doctor should tell you what signs and symptoms you should report and monitor you, depending on the type of organ transplant that you have had.

Complications, including graft-versus-host-disease (GVHD), in people who have received a bone marrow (stem cell) transplant that uses donor stem cells (allogeneic). These complications can be severe and can lead to death. These

Continued on next page.

complications may happen if you underwent transplantation either before or after being treated with KEYTRUDA. Your doctor will monitor you for the following signs and symptoms: skin rash, liver inflammation, stomach-area (abdominal) pain, and diarrhea.

Getting medical treatment right away may help keep these problems from becoming more serious. Your doctor will check you for these problems during treatment with KEYTRUDA. Your doctor may treat you with corticosteroid or hormone replacement medicines. Your doctor may also need to delay or completely stop treatment with KEYTRUDA, if you have severe side effects.

What should I tell my doctor before receiving KEYTRUDA?
Before you receive KEYTRUDA, tell your doctor if you:

- have immune system problems such as Crohn's disease, ulcerative colitis, or lupus
- have received an organ transplant, such as a kidney or liver
- have received or plan to receive a stem cell transplant that uses donor stem cells (allogeneic)
- have lung or breathing problems
- have liver problems
- have any other medical problems
- are pregnant or plan to become pregnant
  - KEYTRUDA can harm your unborn baby.

Females who are able to become pregnant:

  - Your doctor will give you a pregnancy test before you start treatment with KEYTRUDA.
  - You should use an effective method of birth control during and for at least 4 months after the final dose of KEYTRUDA. Talk to your doctor about birth control methods that you can use during this time.
  - Tell your doctor right away if you think you may be pregnant or if you become pregnant during treatment with KEYTRUDA.
- are breastfeeding or plan to breastfeed.
  - It is not known if KEYTRUDA passes into your breast milk.
  - Do not breastfeed during treatment with KEYTRUDA and for 4 months after your final dose of KEYTRUDA.

Tell your doctor about all the medicines you take, including prescription and over-the-counter medicines, vitamins, and herbal supplements.

Know the medicines you take. Keep a list of them to show your doctor and pharmacist when you get a new medicine.

How will I receive KEYTRUDA?

- Your doctor will give you KEYTRUDA into your vein through an intravenous (IV) line over 30 minutes.
- In adults, KEYTRUDA is usually given every 3 weeks or 6 weeks depending on the dose of KEYTRUDA that you are receiving.
- In children, KEYTRUDA is usually given every 3 weeks.
- Your doctor will decide how many treatments you need.
- Your doctor will do blood tests to check you for side effects.
- If you miss any appointments, call your doctor as soon as possible to reschedule your appointment.

What are the possible side effects of KEYTRUDA?
KEYTRUDA can cause serious side effects. See "What is the most important information I should know about KEYTRUDA?"

Common side effects of KEYTRUDA when used alone include: feeling tired, pain, including pain in muscles, bones or joints and stomach-area (abdominal) pain, decreased appetite, itching, diarrhea, nausea, rash, fever, cough, shortness of breath, and constipation.

Common side effects of KEYTRUDA when given with certain chemotherapy medicines include: feeling tired or weak, nausea, constipation, diarrhea, decreased appetite, rash, vomiting, cough, trouble breathing, fever, hair loss, inflammation of the nerves that may cause pain, weakness, and paralysis in the arms and legs, swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, and mouth sores.

Common side effects of KEYTRUDA when given with axitinib include: diarrhea, feeling tired or weak, high blood pressure, liver problems, low levels of thyroid hormone, decreased appetite, blisters or rash on the palms of your hands and soles of your feet, nausea, mouth sores or swelling of the lining of the mouth, nose, eyes, throat, intestines, or vagina, hoarseness, rash, cough, and constipation.

In children, feeling tired, vomiting and stomach-area (abdominal) pain, and increased levels of liver enzymes and decreased levels of salt (sodium) in the blood are more common than in adults.

These are not all the possible side effects of KEYTRUDA. For more information, ask your doctor or pharmacist.

Tell your doctor if you have any side effect that bothers you or that does not go away.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

General information about the safe and effective use of KEYTRUDA

Medicines are sometimes prescribed for purposes other than those listed in a Medication Guide. If you would like more information about KEYTRUDA, talk with your doctor. You can ask your doctor or nurse for information about KEYTRUDA that is written for healthcare professionals. For more information, go to www.keytruda.com.

Based on Medication Guide usmg-mk3475-iv-2006r032 as revised June 2020.

MERCK

INNOVATOR

RIAAN RIFKIN

BY **THERESA MACHEMER** PHOTOGRAPH BY **MARK THIESSEN**

He analyzes DNA from prehistoric pathogens.

As a young teen, bioarchaeologist Riaan Rifkin spent vacations exploring an Iron Age settlement near his home north of Pretoria, South Africa. Hooked on the pursuit, Rifkin now searches for much smaller artifacts of prehistoric life: the DNA of ancient pathogens.

"Imagine living in a cave five or 10 or a hundred thousand years ago," he says. "You never vacuumed or swept. So every meal you had, every visitor you had, everything you did in the cave, there would be bits of DNA of those activities within the sediment."

With the advent of agriculture and livestock, the Iron Age saw the rise of diseases, such as measles, that spread in crowds. Other illnesses, such as mosquito-borne malaria, predate human settlements. Studying diseases' origins could help prevent them today.

Ancient humans learned how to combat the maladies of their day. Some 50,000 years ago, cave dwellers slept on aromatic grasses whose insecticidal properties kept ticks and fleas away. Nomadic peoples learned to move their settlements every few weeks before disease-carrying pests converged on them. Today Himba women in southern Africa cover their bodies in a mix of butterfat and red ocher, a culturally important tradition that also acts as sunscreen and bug repellent.

"We've managed to reconstruct ancient bacterial genomes dating to about 2,500 years ago from South African samples," Rifkin says. "I think within a decade or so, we will be able to push this back further and further." ▯

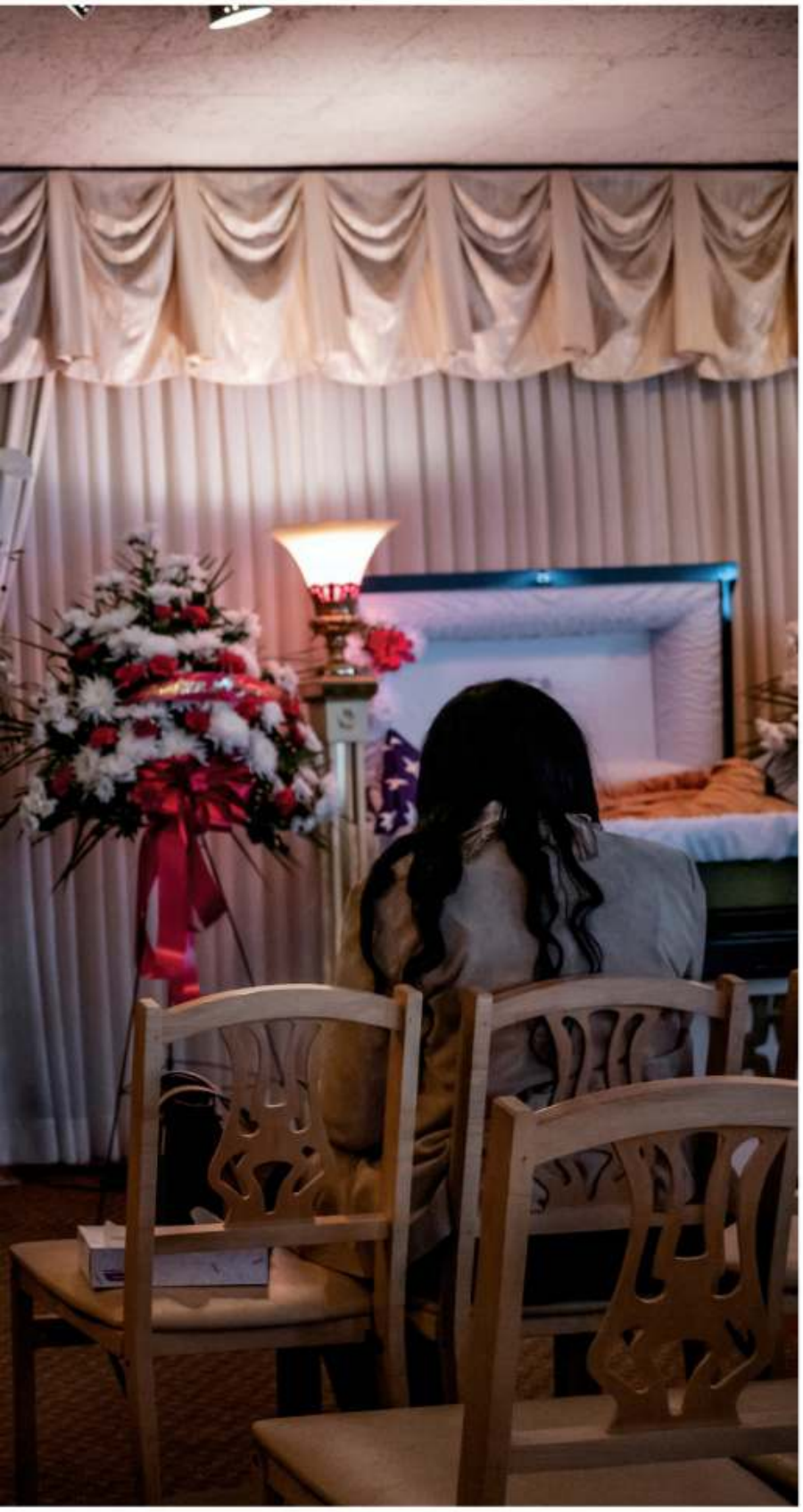
AWESOME LEVEL

NEW SOCKS

NEW PET

Give them the everyday awesome of Lunchables LUNCH COMBINATIONS

Sorrow First, Then Resilience



TO THIS PHOTOGRAPHER, WITNESSING THE STRENGTH OF THE PEOPLE STRUCK BY THE PANDEMIC WAS WORTH THE RISK OF GETTING INFECTED HIMSELF.

STORY AND PHOTOGRAPHS BY
DANNY WILCOX FRAZIER
AS TOLD TO **CASSANDRA SPRATLING**

I TOOK SOME 10,000 PHOTOS during the 12 days I spent in Detroit documenting the impact that the novel coronavirus had on the city's people. I went everywhere, as carefully as I could. City buses that workers depended on to get to and from the jobs they couldn't afford to give up. Houses and apartments where people lived and loved despite illnesses and job losses that threatened their well-being. Funerals where family members had to take turns saying goodbye to their loved ones—no more than 10 people allowed to gather at a time.

Ten. That happens to be the number of children that Chester Lovett had. The Marine veteran and former mail carrier also had a mother, grandchildren, brothers, nieces and nephews, and countless others who loved him. Yet the 59-year-old died in a hospital without any of them by his side. That's the way it was then.

His funeral was heart wrenching and beautiful. For me, his family's palpable grief was made worse knowing that the virus wouldn't have overwhelmed people of color if the United States treated its Black and brown citizens equitably. Instead, COVID-19 was sickening and killing them at disproportionate rates.

Lovett's relatives couldn't share the service together. They had to rotate in and out. His brother Jerry spoke eloquently about what a great family and community man Lovett was. Other family members wrote loving tributes, some made light with humor. They all talked about how gentle and caring he had been. Like me, he loved to travel.

I photographed Deontaye Clay, an employee of the Wilson-Akins Funeral Home, as he sang a soul-stirring rendition of the gospel hymn "Oh to Be Kept by Jesus." Kenny Alexander accompanied Clay while wearing a respirator, a visible sign of the danger faced simply by playing an organ at a funeral.

As the funeral director prepared to close the casket, some of Lovett's children gathered nearby, while others remained in their seats, separate but united. It was such an emotionally heavy scene. I put my camera to my face and cried. In 20 years of making photographs, I've never done that.

Afterward, a marine marched up the aisle to begin the military's ceremonial goodbye. She saluted Lovett's casket as another marine played taps on a bugle, the sobering sound coming clearly from outside. The two service members folded an American flag and presented it to Lovett's mother.

Outside, the family gathered around as best they could while Jerry Lovett released a dove to the sky, a symbol of his brother being released to heaven. I saw it also as a sign of hope rising from tragedy—hope for the family, for the city, for our nation. The funeral ceremony was as powerful and painful as anything I've ever seen.

I returned home to Iowa a few days later, exhausted after 16- to 18-hour workdays. But I felt confident that I had a collection of photographs that told Detroit's story of resilience in the midst of tragedy and showed

Danny Wilcox Frazier photographs Thomas Ferra and Sarah Smith in the motel room where they've lived since Smith lost her job.

what it looks like when our nation leaves so many of its citizens defenseless against a pandemic.

I'd been careful while shooting—always wearing protective gear, disinfecting equipment before and after photographing, washing clothes daily, and not putting my camera equipment down anywhere. Even so, I quarantined in an Airbnb that my wife, Lydia, found near one of our town's hospitals.

I moved in there on a Tuesday. I was careful then too. I wore an N95 mask when I went outside, even while climbing the stairs that led to my temporary home.

By Thursday, I noticed that I was breathing more heavily than usual. I thought nothing of it. I figured the mask and the long stairs were taking a toll.

By Saturday, I was congested and coughing. My nose ran; my muscles ached. Darn seasonal allergies, I thought. But the usual medicines didn't work. I napped during the day but couldn't sleep at night. I must have a stubborn version of the seasonal flu, I explained to my wife and my editor. I still suspected flu when the symptoms morphed and everything I ate ran through me.

On Monday I finally called my doctor. Based on my symptoms, she thought I had COVID-19. If my fever hit 102.5, she told me, I had to go to the hospital.

I'd just spent two weeks covering people sick or dead from the virus, and I never suspected I had it. I thought I'd taken extra precautions.

On Tuesday I pushed through a long editing session of the Detroit photographs. Afterward my temperature climbed: 100, 100.5, 101.5, 101.8. I didn't want to go to the hospital. The very idea made me anxious. I knew too many people like Lovett, people who had gone into the hospital and had died.

As bad as I felt physically, I felt even worse emotionally. I thought I'd let my family down: I'd promised them I wouldn't get sick. I thought I'd let my subjects down too, and my editor at *National Geographic,* who had trusted me with the assignment and outfitted me with plenty of protective gear.

My temperature topped out at 101.8.

On Wednesday I fell asleep while on hold with the doctor's office. When I woke up more than an hour later, my phone lying next to me, I was as sweat soaked as if I'd just finished a long workout. My fever had broken. But other symptoms lingered a couple of weeks longer: low energy, muscle weakness, headaches.

I knew the risks of going to Detroit. Even now I think it was worth it. It was worth the risk to tell the stories of people like the workers at the Motor City Mitten Mission who, despite the virus, never stopped delivering food to people hungry for it.

It was worth the risk to tell the story of Tiyea Jackson and his family, who were living in a motel because Jackson had been laid off from an auto parts supplier that shut down during the pandemic. They were so low on funds that the Mitten Mission had to pay their bill, yet at night they talked and laughed and read Bible verses together. They could have lost all hope, but they didn't.

It was especially worth the risk to tell the story of the Lovett children, who lost their father in such a painful way but were held together by the love they shared with him.

My experience in Detroit affirmed what I believe: that whatever hardships we face, we will make it through if we come together as families, as communities, as states, and as a nation that cares about all of its people. Not just the wealthiest. That's my greatest fear—that we will become a nation where only the wealthiest survive and thrive. ▯

Danny Wilcox Frazier's photographs of the pandemic appeared in the National Geographic online dispatch "Detroit's winning spirit helps it fight back against COVID-19." That article was written by **Cassandra Spratling,** a veteran of the *Detroit Free Press.* Frazier is fully recovered from his bout with COVID-19.

By Thursday, I noticed that I was breathing more heavily than usual.
I thought nothing of it.
I figured the mask and the long stairs were taking a toll.

NGM MAPS

For your redefining what ‘guard dog’ means side.

Nationwide® has the best pet insurance for little dogs who think they’re big dogs—and vice versa.

Get a quote for your pet, no matter how small or big.

petinsurance.com • 855-630-7063

For your many sides, there’s Nationwide.®
insurance | investments | retirement

Nationwide®
is on your side

Bruce and Kate, protected by Nationwide® since 2017

GET CLOSER

TRAVEL WITH NATIONAL GEOGRAPHIC

Natural wonders, legendary wildlife, historic treasures: experience the world up close with National Geographic's experts and make a difference. When you travel with us, you help support the scientists, explorers, and storytellers who are working to understand and protect our planet.

NATIONAL GEOGRAPHIC

EXPEDITIONS

NATGEOEXPEDITIONS.COM | 1-888-351-3274

FEATURES

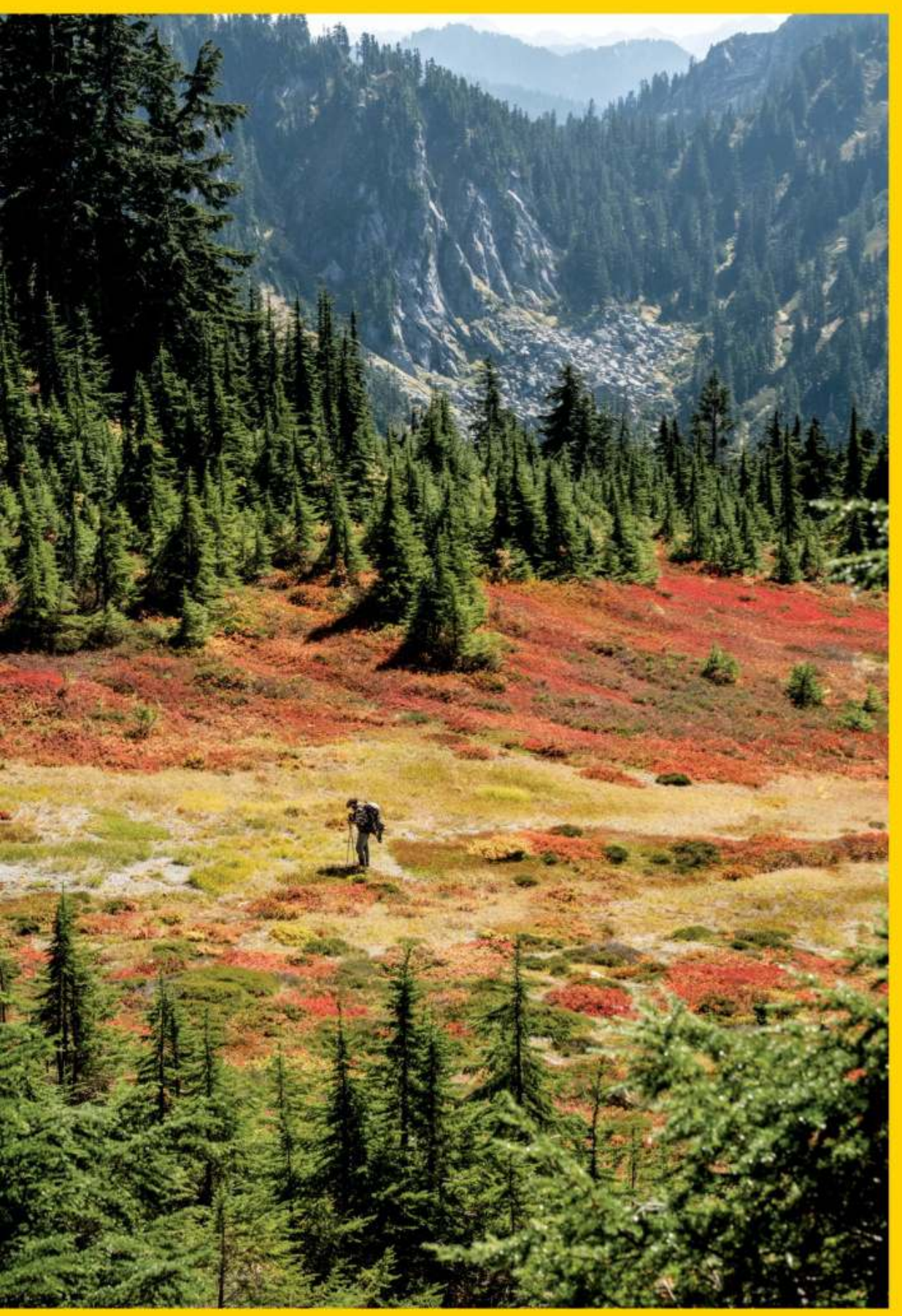


PHOTO: ZACHARY KRAHMER

128

‘THE WAY TO UNDERSTAND RUSSIA MAY BE TO TAKE THE TRANS-SIBERIAN RAILWAY ACROSS THE ENDLESS STEPPE. TO SEE AUSTRALIA, FLY. IN VENICE, HOP INTO A GONDOLA. BUT TO APPRECIATE AMERICA, TAKE A HIKE.’

Nicholas Kristof, author, ‘Our Trails, Our Legacy’

More than anything else, scientific advances show us that dinosaurs weren't the one-note menaces we often see in pop culture. Their days were as rich and varied, frenzied and humdrum, as those of the animals outside our windows.

Some 166 million years ago in what is now Oxfordshire County, England, the ground trembled with the footfalls of the first dinosaur to be scientifically described, *Megalosaurus*. When the animal was sculpted for London's Crystal Palace Park in the 1850s (left), the artist took cues from modern crocodiles. Scientists now know the dinosaur was bipedal (below).

BY **MICHAEL GRESHKO**

PHOTOGRAPHS BY **PAOLO VERZONE**

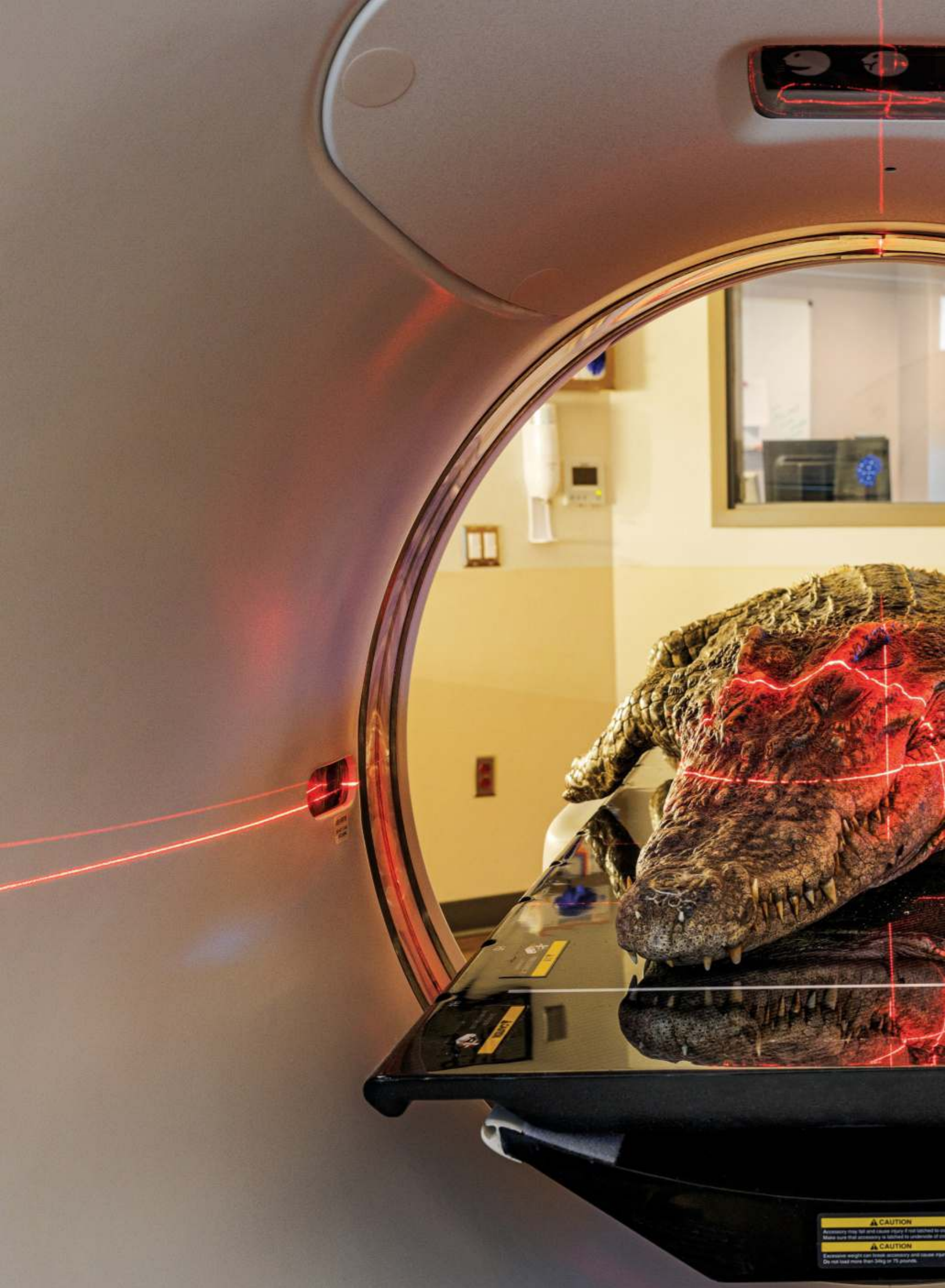
PAINTINGS BY **DAVIDE BONADONNA** AND GRAPHIC ILLUSTRATIONS BY **GABRIEL UGUETO**

Using innovative scientific techniques and a flood of recently discovered fossils, paleontologists are rewriting what we know about the ancient beasts—from the color of their skin and feathers to how they were raised, how they lived, and how they evolved.

REIMAGINING

DINOSAURS

Shovels scrape and pickaxes fly in the Moroccan Sahara, where a team of paleontologists, students, and expert diggers search for fossils of the dinosaur *Spinosaurus aegyptiacus*. Bones found at this site reveal that *Spinosaurus* had a tail built for aquatic propulsion, the first ever found on a large predatory dinosaur.


CAUTION
CAUTION

For more than two decades a cavalcade of frozen carcasses has passed through the CT scanners of Ohio's O'Bleness Hospital, including this Siamese crocodile. Lawrence Witmer, a paleontologist at nearby Ohio University, uses scans of modern animals to reconstruct and interpret the internal anatomy of extinct dinosaurs.

ON

This *Mantellisaurus,* unearthed in 1914 and displayed in the U.K.'s Natural History Museum, was named an *Iguanodon* before scientists recognized it as its own genus in 2007. Roughly 125 million years old, the skeleton is one of the most complete dinosaur fossils ever found in the U.K.

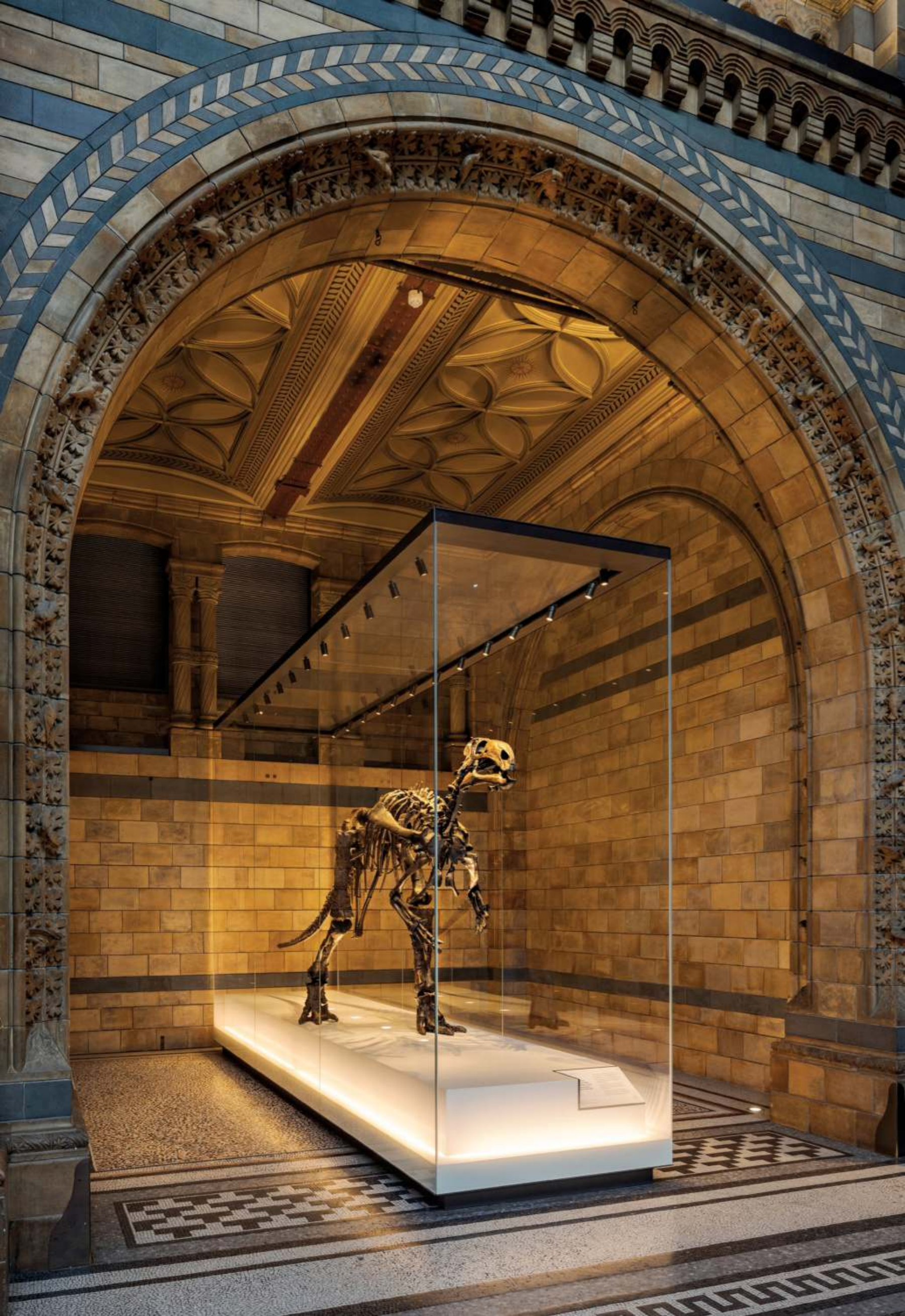
a chilly January afternoon, Susannah Maidment stands on the shore of a London lake, staring down a pack of dinosaurs.

Maidment, a curator at the U.K.'s Natural History Museum, has come with me to tour Crystal Palace Park, which in 1854 included the world's first public dinosaur showcase. The sculptures were a smash hit at their unveiling and sparked the dinomania that's been with us ever since. More than a century before Steven Spielberg dazzled the world with *Jurassic Park*, the Crystal Palace dinosaurs drew two million visitors a year for three decades straight, and Charles Dickens name-dropped one in his novel *Bleak House*.

To grant us a detailed look at these 166-year-old monuments, Ellinor Michel and Sarah Jayne Slaughter, trustees with the nonprofit Friends of Crystal Palace Dinosaurs, guide us through a metal gate to the banks of the lake, where we don waders to make our crossing. I misjudge my first step and fall into the water, clambering onto the island's shore, dripping wet and smelling of pond scum. "Welcome to Dinosaur Island!" Slaughter exclaims, grinning from ear to ear.

Tucked in among ferns and spongy beds of moss, the pale green sculptures are imposing, even imperious. The park's two *Iguanodon*, a Cretaceous herbivore, resemble huge iguanas with nubs on their snouts—which scientists now understand were spikes on their thumbs. It's tempting to dismiss the assemblage as outdated or the stuff of B movies. But Maidment sees the Crystal Palace dinosaurs for what they really are: the bleeding edge of scientific knowledge at the time, based on comparisons between living animals and the few fossils available to researchers.

Scientists still use this technique to re-create the fantastic beasts, filling in the soft gaps in time-worn fossils. Bones don't preserve evidence of cheeks on ancient faces, Maidment says, as we pause between two of the statues, "but we



reconstruct them as being there because it works: Animals today have cheeks." The park's sculptors used the same process, she says. "They were completely reasonable to reconstruct them like this from what they knew."

In the nearly two centuries since, scientists have learned far more about dinosaurs than the builders of Crystal Palace Park ever could have dreamed. Now our understanding is seeing another revolution—one fueled by a wealth of fresh fossils and innovative research techniques. The resulting scientific bonanza is forcing us to rethink popular visions of these ancient animals.

For several years scientists have unveiled an average of about 50 new dinosaur species a year, a pace unthinkable decades ago. The updated menagerie ranges from pint-size fliers with bat wings to long-necked herbivores that were Earth's biggest ever land animals. Medical scanners, particle accelerators, and chemical analyses are letting researchers virtually separate rock from bone and see fossils' tiniest hidden features. From the colors of dinosaurs' eggs and feathers to the shapes of their brains, our dino encyclopedia

Beyond hosting displays, museums protect and study a range of fossils. The U.K.'s Natural History Museum maintains the only known bones of *Adratiklit*, the oldest stegosaur ever found. In 2019 a team led by staff curator Susannah Maidment declared *Adratiklit* a new genus, in part based on the arm bone she holds here.

now includes unprecedented details on how these animals were born, grew up, and lived.

With these tools in hand, scientists today are not just overhauling our pop-culture notions about dinosaurs; in a sense they are bringing these remarkable creatures back to life. When it comes to dinosaur discovery, "I do genuinely think the golden age is right now," says University of Edinburgh paleontologist Steve Brusatte.

IT'S FITTING that dinosaurs are so persistently captivating. For 150 million years they dominated landscapes across ancient Earth, and they lived on what are now all seven continents. Dinosaurs were hugely successful during their reign, adapting into a bevy of shapes and sizes.

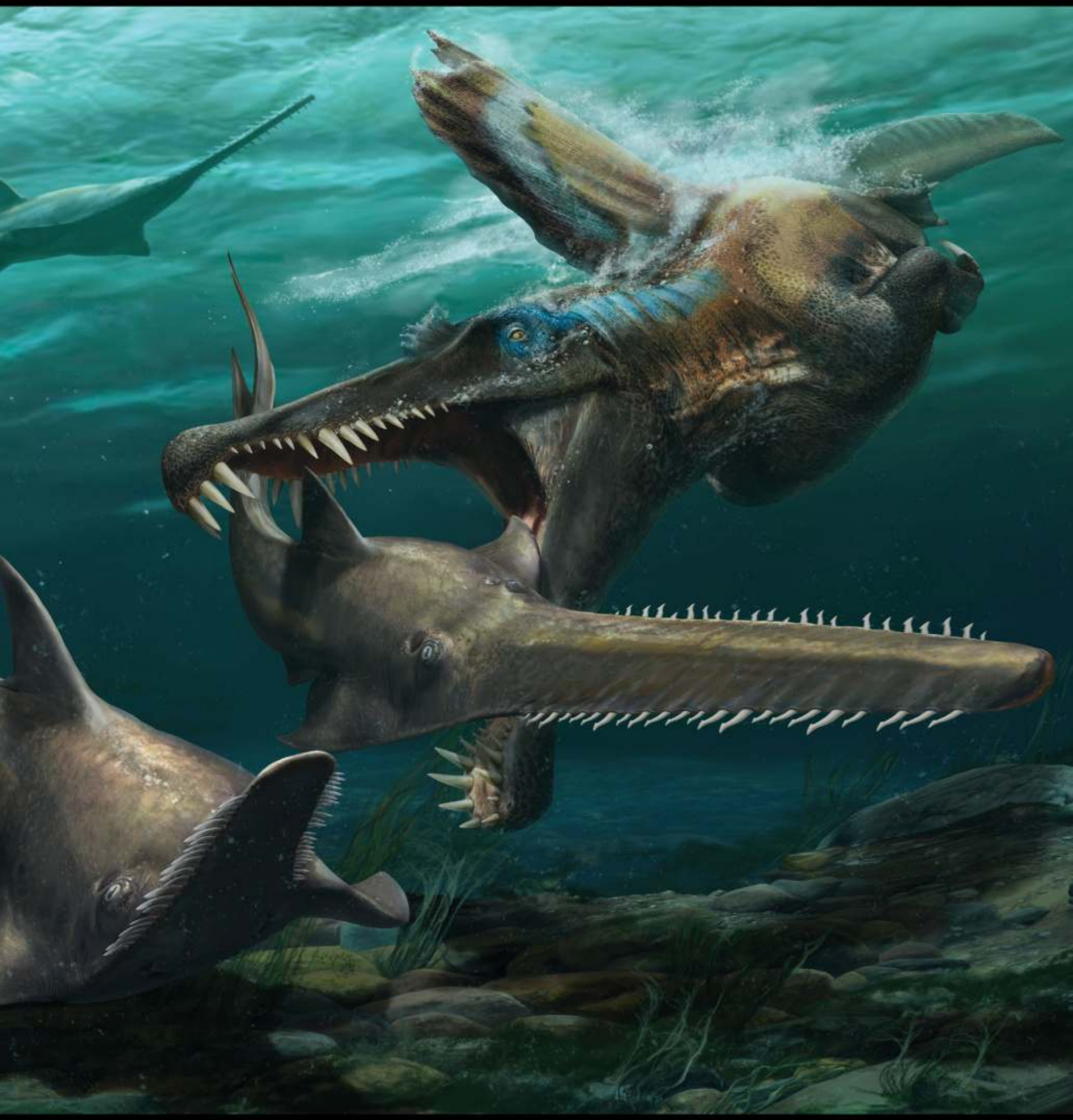
Brusatte and others estimate that scientists have cataloged more than 1,100 species of extinct dinosaurs, and that's just a subset of the species that once lived, because fossilization occurred in only a few environments. Their story continues to this day. When an asteroid slammed into Mexico's Yucatán Peninsula 66 million years ago and wiped out three-quarters of life on Earth, one group of dinosaurs survived: the feathery creatures we now call birds.

Western science has formally studied dinosaurs only since the 1820s, but what we've learned reveals a lot about how land animals are affected by our ever changing planet.

As continents drifted apart and recombined—and as temperatures and sea levels rose and fell—dinosaurs persisted. What lessons can we take from their responses and resilience? Telling such an epic story requires a worldwide hunt for dinosaurs' bones, and from Alaska to Zimbabwe, paleontologists are delivering as never before.

One of the richest regions for new fossil finds is North Africa. Someone sweltering in the 105-degree heat of the Moroccan Sahara may find it tough to imagine that this landscape was once lush with waterways deep enough to host car-size fish. But National Geographic Explorer Nizar Ibrahim and his crew of paleontologists have returned to the region for years, chasing one of the weirdest dinosaurs ever found: a river monster called *Spinosaurus aegyptiacus*.

The first *Spinosaurus* fossils were discovered in Egypt in the 1910s but were destroyed in a World War II bombing raid in Germany. Still, surviving field notes, sketches, and photographs



01

Two *Spinosaurus aegyptiacus* hunt the sawfish *Onchopristis* in a river system that covered what is now Morocco more than 95 million years ago.

SOURCE: NIZAR IBRAHIM, NATIONAL GEOGRAPHIC EXPLORER

WHAT'S NEW

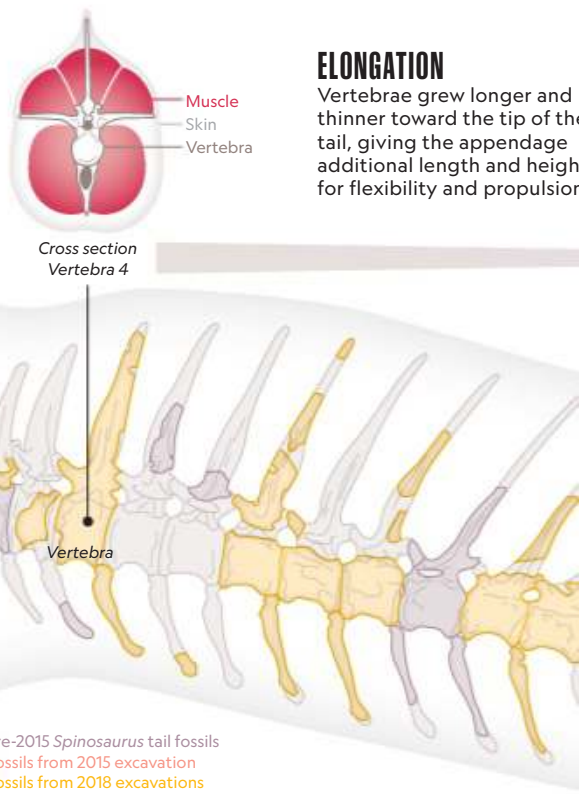
A groundbreaking discovery provides evidence that Spinosaurus was mostly aquatic. It had a tail designed for propulsion in water, a forward-leaning center of gravity good for swimming, and curved claws more suited to catching prey in water than to walking on land.

HOW THEY

MOVED

HOW THEY MOVED

SWIMMERS AN



ELONGATION

Vertebrae grew longer and thinner toward the tip of the tail, giving the appendage additional length and heigh for flexibility and propulsion

FLIGHT TEST

Did dinosaurs take wing from the ground or glide down from trees—or both? To test these hypotheses, scientists used computer simulations, robot models, and even animals of today in multiple experiments.

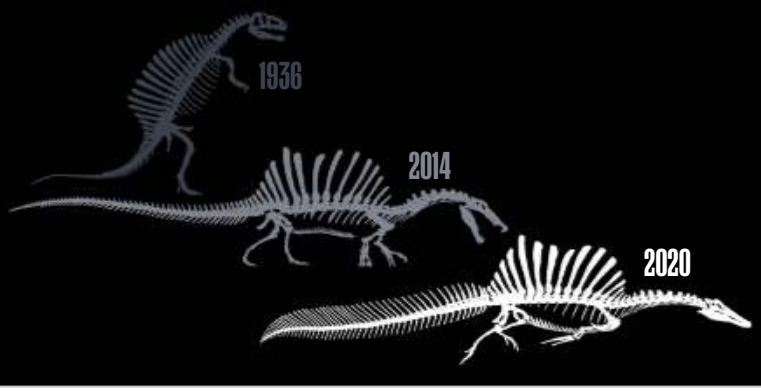
From the ground up

To study the possible origins of flight, researchers used an ostrich as a body double for *Caudipteryx* to see how it used its wings for balance while running. They outfitted the ostrich with mechanical wings and force sensors to measure wing motion and lift.

Caudipteryx

JASON TREAT, NGM STAFF; MESA SCHUMACHER. SOURCES: NIZAR IBRAHIM, NATIONAL GEOGRAPHIC EXP
ANGELES COUNTY; YASER TALORI AND OTHERS, *COMPUTATIONAL BIOLOGY*, MAY 2019; GARETH DYKE AN

D FLIERS



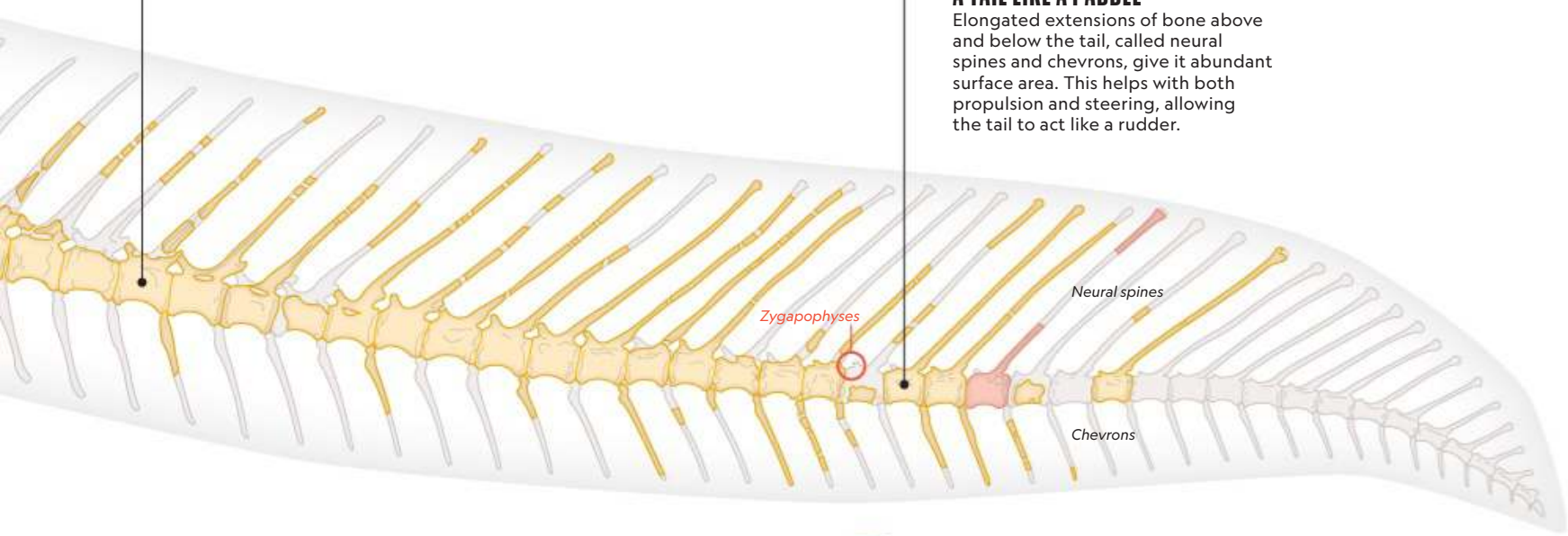
HOW OUR THINKING HAS CHANGED
Before 2014, paleontologists had only fragments of *Spinosaurus*'s tail and theorized it was rigid, like those of other theropods. As more fossils came to light, the understanding of how the dinosaur moved changed from it being a landlubber to a shallows wader to a skillful swimmer.

Cross section Vertebra 15

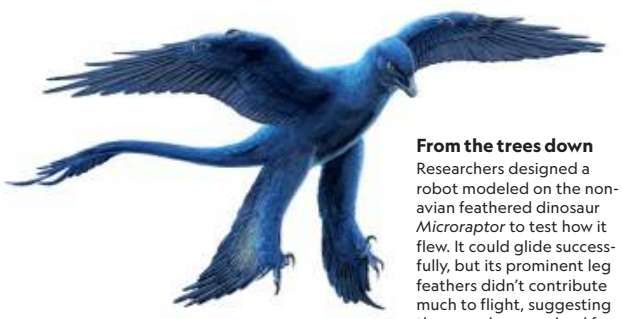
Cross section Vertebra 31

LATERAL FLEXIBILITY
Unlike tails on other theropods, bony overhangs on the vertebrae called zygapophyses are small and barely overlap. This allows the tail to flex laterally, acting more like a flexible chain than a reinforced rod.

A TAIL LIKE A PADDLE
Elongated extensions of bone above and below the tail, called neural spines and chevrons, give it abundant surface area. This helps with both propulsion and steering, allowing the tail to act like a rudder.



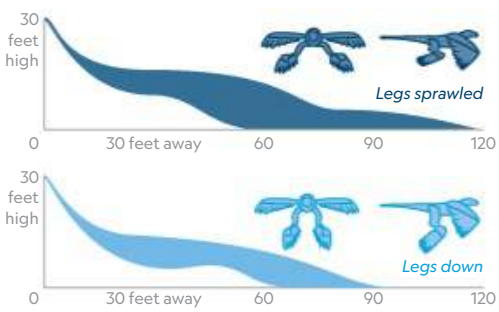
Ostrich with wing harness



Microraptor

From the trees down
Researchers designed a robot modeled on the non-avian feathered dinosaur *Microraptor* to test how it flew. It could glide successfully, but its prominent leg feathers didn't contribute much to flight, suggesting they may have evolved for some other use.

Gliding performance for *Microraptor* model
by body configuration



LORER; MICHAEL HABIB, NATURAL HISTORY MUSEUM OF LOS
D OTHERS, *NATURE COMMUNICATIONS*, SEPTEMBER 2013

of the original fossils, along with a few isolated bones and teeth found later in the 20th century, hinted that this mysterious, sail-backed creature had some kind of aquatic lifestyle. *Spinosaurus* had conical teeth well adapted for nabbing fish, for example, so paleontologists surmised that it perhaps prowled the shallows and plucked fish out of the water, as herons or grizzly bears do. Ibrahim and his colleagues therefore made a huge splash in 2014 when they described a new partial skeleton of the animal found in Morocco, and used it to make the case that *Spinosaurus* spent much of its time swimming and feeding in the water.

To buttress the claims, Ibrahim's team returned to the arid site in 2018 with the support of the National Geographic Society in hopes of finding more parts of the creature. The dig was brutal. To clear tons of rock, the crew bought the region's only working jackhammer, which broke within minutes, forcing them to seek repairs from the seller of the defective tool. Several team members were hospitalized for exhaustion once they returned home. But fueled by Nutella and

Huddled in a lab at Morocco's Hassan II University, National Geographic Explorer Nizar Ibrahim (center) examines *Spinosaurus* bones with paleontologists Simone Maganuco (at left) and Cristiano Dal Sasso. "To study a fossil animal is, to me, a sort of creation," Dal Sasso says. "You have to resurrect an animal from fragments."

the promise of discovery, they started finding one vertebra after another from *Spinosaurus*'s tail, sometimes just minutes and inches apart. The diggers were so giddy over the trove of fossils, they drummed out musical beats with their rock hammers and broke into song.

Shaped like a paddle some 17 feet long, the unearthed appendage, unveiled earlier this year in the journal *Nature,* is the most extreme aquatic adaptation ever found in a large predatory dinosaur. It's a hard-won revelation that stretches the outer bounds of how researchers thought dinosaurs moved through their environments. "This is going to become a symbol, an icon, of African paleontology," Ibrahim tells me.

THE STORY of *Spinosaurus,* with its desert vistas and historical intrigue, feels as if it could have been lifted from a movie script. But subsequent research on the fossil tail has shown just how different today's study of dinosaurs can be.

As part of his work, Ibrahim traveled from Casablanca to Cambridge, Massachusetts, and the Harvard University lab of biologist George Lauder. By his own admission, Lauder is no paleontologist: He specializes in studying how aquatic animals move in water, using high-speed cameras and robots to figure out how they swim. To put *Spinosaurus* to the test, Lauder mounts an eight-inch-long, orange plastic cutout of the dinosaur's tail to a metal rod attached to a $5,000 force transducer—part of a robotic "flapper" that dangles from the ceiling.

"It's like a medieval torture device," quips Harvard paleobiologist Stephanie Pierce, who designed and led the experiments, as Lauder lowers the robot into a flume.

Once submerged, the mounted tail springs to life, flapping back and forth and sending data from the apparatus to nearby computers. Pierce and Lauder's results show that *Spinosaurus*'s tail could deliver more than eight times the forward thrust in water of the tails of related, landlubbing dinosaurs. A beast longer than *Tyrannosaurus rex* appears to have swum its way through rivers like a crocodile. "Where we started was, a dinosaur paleontologist gets in touch with another paleontologist, who gets in touch with a fish bioroboticist," Pierce says. "If you want to do modern, cutting-edge *(Continued on page 72)*

As new dinosaur discoveries pile up, so does the need to revise models of the creatures. In Fossalta di Piave, Italy, craftsman Guzun Ion of the museum sculpture firm DI.MA. Dino Makers molds an updated tail for a life-size re-creation of a 34-foot-long *Spinosaurus* subadult.

02

A newly hatched *Deinonychus* chick is surrounded by colorful blue eggs in an aboveground nest. It's watched over by an attendant father.

SOURCE: JASMINA WIEMANN, YALE UNIVERSITY

WHAT'S NEW

Deinonychus appears to have had bluish eggs like those of some modern birds, suggesting it used open-air nests. Egg color and patterning may provide camouflage in an open environment; nests in the open would indicate that Deinonychus brooded its offspring.

HOW THEY

HATCHED

HOW THEY HATCHED

COLORED EGGS

Pigment creators
When struck with a laser, *Eumaniraptora* eggshells reveal two chemicals that help determine color and speckling in modern bird eggs.

Roosting ▲
Modern birds with hard-shelled eggs usually brood their young in open nests. The behavior may have evolved when coloration did, 157 million years ago.

Buried nests ▼
Some dinosaurs, such as *Protoceratops*, had eggs with soft, leathery shells. To protect them, the dinosaurs would have buried their eggs, much as sea turtles do today.

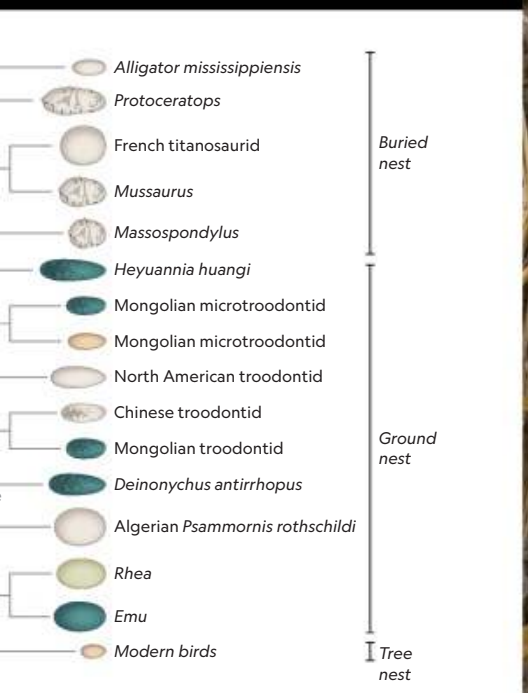
A LOOK INSIDE

No need to crack any dinosaur eggs—researchers can see inside with CT scans. Embryonic teeth have deposits that can be counted like tree rings, helping researchers calculate incubation times. They found that dinosaur incubation was slower than birds and closer to reptiles.

JASON TREAT, NGM STAFF; MESA SCHUMACHER
SOURCES: KIMI CHAPELLE AND VINCENT FERNANDEZ, WITS UNIVERSITY; JASMINA WIEMANN AND OTHERS, *NATURE*, OCTOBER 2018

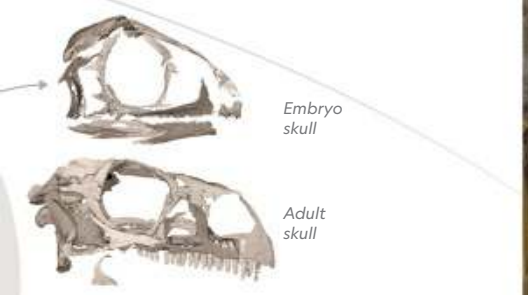
HOW OUR THINKING HAS CHANGED

Previous theories about dinosaur reproduction relied heavily on our understanding of reptile eggs. Scientists have since established a solid evolutionary connection between dinosaurs and birds, one that is yielding better clues to how dinosaurs laid eggs and cared for their young.



COLOR COORDINATION

Scientists have recently found that many dinosaur eggs had the colorful hues and mottled specks of modern bird eggs. Egg color tends to match the nesting background.



Re-created skulls

CT scans create a stack of x-ray pictures. Reconstructed 3D models of *Massospondylus* embryos found extra teeth that were later shed (as modern geckos do).

Bird eggs, such as these from tinamous, get their colors from pigments including protoporphyrin and biliverdin. Some fossil dinosaur eggs preserve these two compounds, hinting at their hues.

PHOTOGRAPHED AT PEABODY MUSEUM OF NATURAL HISTORY, YALE UNIVERSITY

This fossilized bird egg from what is now Nebraska was laid tens of millions of years after the extinction of the non-avian dinosaurs. Even so, the remains help Yale Ph.D. candidate Jasmina Wiemann analyze the chemistry of more ancient eggshells. "All birds are dinosaurs, so it is also an avian dinosaur egg," she says.

PHOTOGRAPHED AT PEABODY MUSEUM OF NATURAL HISTORY, YALE UNIVERSITY

03

A young *Mussaurus* observes two rhynchosaurs under the gaze of an adult. *Mussaurus* started life on four legs, becoming bipedal by adulthood.

SOURCES: JOHN R. HUTCHINSON, THE ROYAL VETERINARY COLLEGE; ALEJANDRO OTERO, CONICET–MUSEO DE LA PLATA

WHAT'S NEW

Researchers now better understand the entire life cycles of certain dinosaurs. New finds are helping them piece together how dinosaurs developed, matured, and sometimes reached enormous sizes.

HOW THEY GREW

HOW THEY GREW

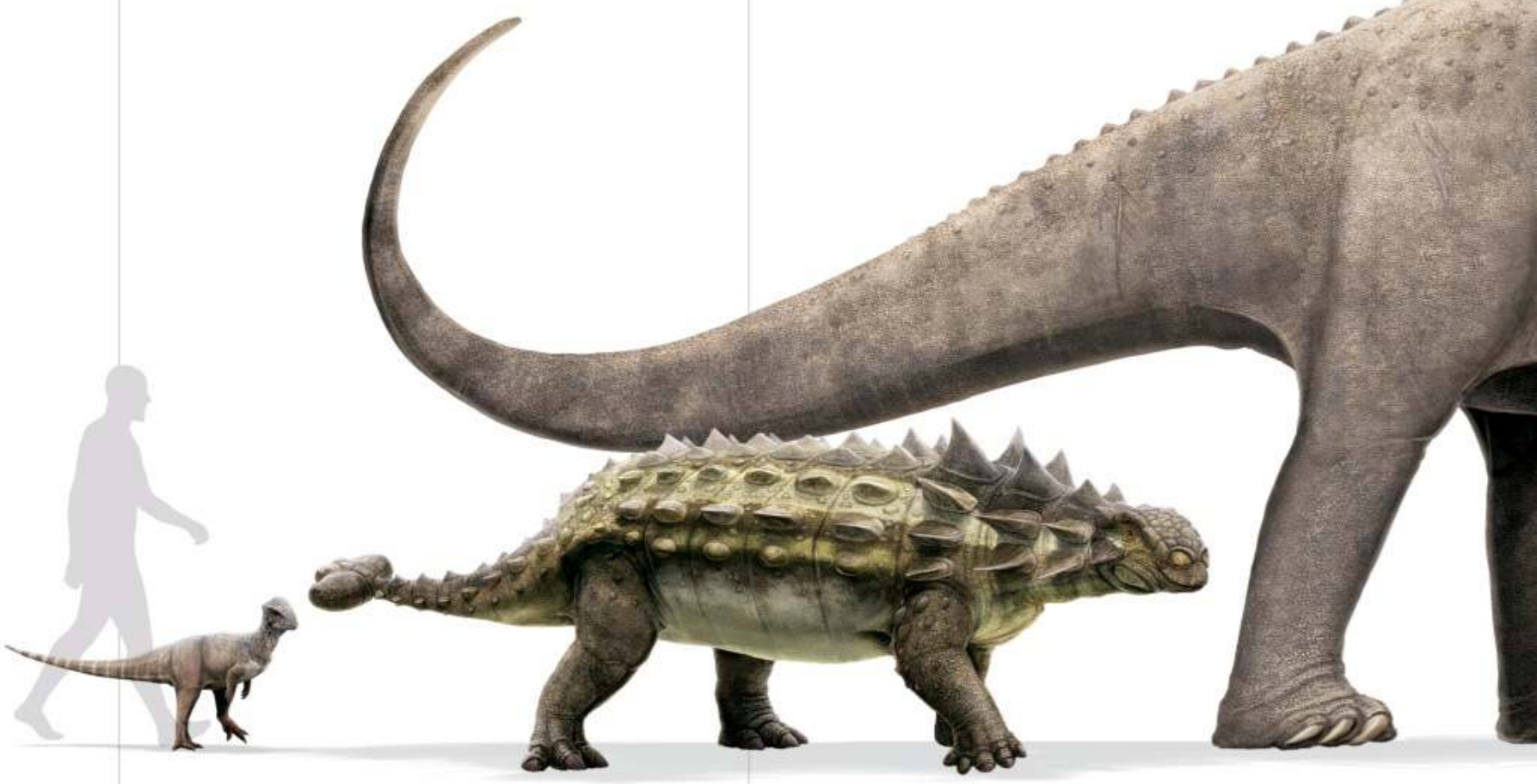
HOT BODIES, COOL HEADS

SMALLER AND COOLER

Small dinosaurs had a high surface-area-to-volume ratio that maximized their ability to shed heat without special adaptations. Most dinosaur species grew larger over time, but paravian theropods—the precursors of birds—grew smaller over time, which was eventually helpful for flight.

BIGGER AND HOTTER

Giant sauropods, the largest animals to walk the Earth, could top 110,000 pounds. How to get so big? Grow slowly over a long life, like crocodiles, or grow fast, which these dinosaurs did. Reaching full size within 20 years, sauropods' low surface-area-to-volume ratio supported a fast metabolism but required special adaptations to shed heat.

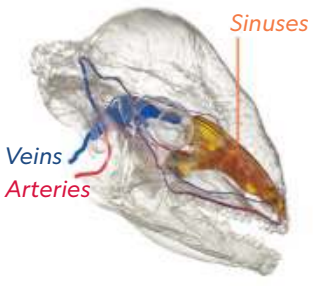


SMALL-BODIED DINOSAURS

Evenly distributed blood flow

Stegoceras

Because of its small size, this dinosaur likely kept cool by modifying its behavior. It didn't need adaptations to keep its brain cool; blood flow in the head was balanced.



MEDIUM

Heat regulation in nasal cavity

Euoplocephalus

At nearly three tons, this armored dinosaur had a series of specialized looping nasal passages through which enlarged blood vessels could let off excess heat.

HOW OUR THINKING HAS CHANGED

Dinosaurs were thought to have been cold-blooded, like modern reptiles. But new signs of rapid growth rates show that some may have had faster metabolisms than suspected, possibly resembling those of warm-blooded mammals and birds. Some dinosaurs were even at risk of overheating.

A NOVEL APPROACH

Non-avian theropods had a special way to keep cool. When they opened their mouth, the jaw muscles pulled on a unique pair of balloon-like sinuses, expanding them like bellows to draw in air. Blood vessels surrounding the sinuses warmed the air, then closing the jaw forced heat out of the nose and mouth.

LARGE

Heat regulation in nasal cavity and mouth

Camarasaurus

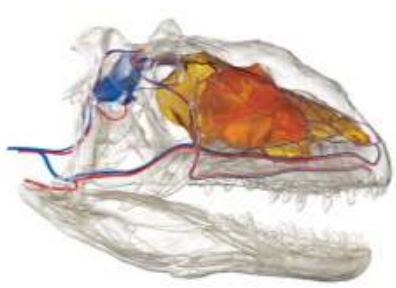
The animals' bulk and fast metabolism kept their internal temperatures high. They released excess heat through thermal transfer areas in their nasal passages and mouth.

INNOVATION IN THEROPODS

Jaw-powered cooling

Majungasaurus

Movement of this medium-size theropod's jaw sent air to a pair of sinuses in the snout that acted like air-conditioning units to cool blood going to the brain.



JASON TREAT, NGM STAFF; MESA SCHUMACHER
3D RENDERINGS: SINELAB. SOURCES: RUGER PORTER AND LAWRENCE WITMER, OHIO UNIVERSITY

(Continued from page 57) research, it takes a team of people from very diverse backgrounds."

These kinds of interdisciplinary lab experiments now define dinosaur research. Modern computers let scientists crunch through huge data sets of skeletal features and build dinosaur family trees. Close examinations of bone slices thinner than sheets of printer paper reveal, in detail, the length and timing of dinosaurs' growth spurts. And with the same models used to forecast climate change, paleontologists can virtually sling an asteroid at Earth as it was 66 million years ago, to watch dinosaur habitats shrink in the resulting apocalyptic winter.

Few technologies have so profoundly altered our view of dinosaurs as medical CT scanning, which is now a standard in the paleo tool kit.

"We've been able to pull all of these extinct bones into a computer, where we can do things with them," says Ohio University paleontologist Lawrence Witmer. "We can reconstruct missing bits … and do crash tests and run simulations and better understand how these animals actually functioned."

Lawrence Witmer stares into a *Tyrannosaurus rex* skull cast in his Ohio University lab. The contours of *T. rex*'s braincase show paleontologists that the animal relied heavily on its sense of smell. A 2019 study inferred that *T. rex* likely had 1.5 times as many genes for odor receptors as humans do, based on the relative size of the brain region that processes scents.

Scanning also eliminates a past trade-off: whether to sacrifice a fossil's soft-tissue imprints to whittle down to bones. Stories abound of dinosaur skin impressions being ground to dust during preparation. Now, researchers virtually cleave bone from rock. "It does make you wonder, what things have we overlooked or bulldozed through?" says Mark Witton, a paleoartist at the U.K.'s University of Portsmouth.

The field's modern sense of caution has yielded an avalanche of discoveries. Recently Witmer used CT scans to show that major groups of dinosaurs evolved distinct cranial air-conditioning systems to keep their brains from overheating. Armored dinosaurs, such as the ankylosaur *Euoplocephalus*, relied on their nasal passages, which evolved into ducts shaped like crazy straws to shed heat as the animal breathed, cooling the blood destined for the brain. By contrast, large predators such as *T. rex* vented excess heat with large snout sinuses. Like blacksmiths working bellows, the dinosaurs flexed their jaws to force air in and out of the chambers, causing moisture to evaporate and wick away heat, like sweat on a summer day.

CT scans also can give us a sense of how dinosaurs moved and changed as they grew. Using x-ray videos and computer animations of alligators and birds, the University of South Florida's Ryan Carney built 3D models that revealed in 2016 that the feathered dinosaur *Archaeopteryx* could flap its wings in a way that enabled self-powered flight. And to understand how the Patagonian herbivore *Mussaurus* grew up, Argentine researcher Alejandro Otero assembled scans of the dinosaur's bones in a computer to simulate its stance at different ages. Just like human babies, *Mussaurus* hatchlings walked on all fours and then matured into walking more upright on their two hind limbs.

The deeper paleontologists can look into each new bit of bone, the more they can unravel precious details about the past—and that means they've had to seriously scale up their tools.

IN THE NORTHWESTERN corner of Grenoble, France, on a triangular spit of land where two rivers meet, a gray ring half a mile around rises out of the smog. It's as if aliens had touched down in the Alps for some skiing and a spot of fondue. The eerie structure is the European Synchrotron

04

A *Yi qi* glides above while two pheasant-size *Tianyulong* bathe. Soft-tissue analysis shows *Yi qi* had membranous wings between its fingers.

SOURCES: MICHAEL HABIB, NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY; MICHAEL PITTMAN, UNIVERSITY OF HONG KONG

WHAT'S NEW

Our understanding of how dinosaurs looked continues to evolve. Researchers now know that many dinosaurs had feathers of some kind that came in a variety of colors, based on their fossilized pigments. Other species had patterned skin coloring for display or camouflage.

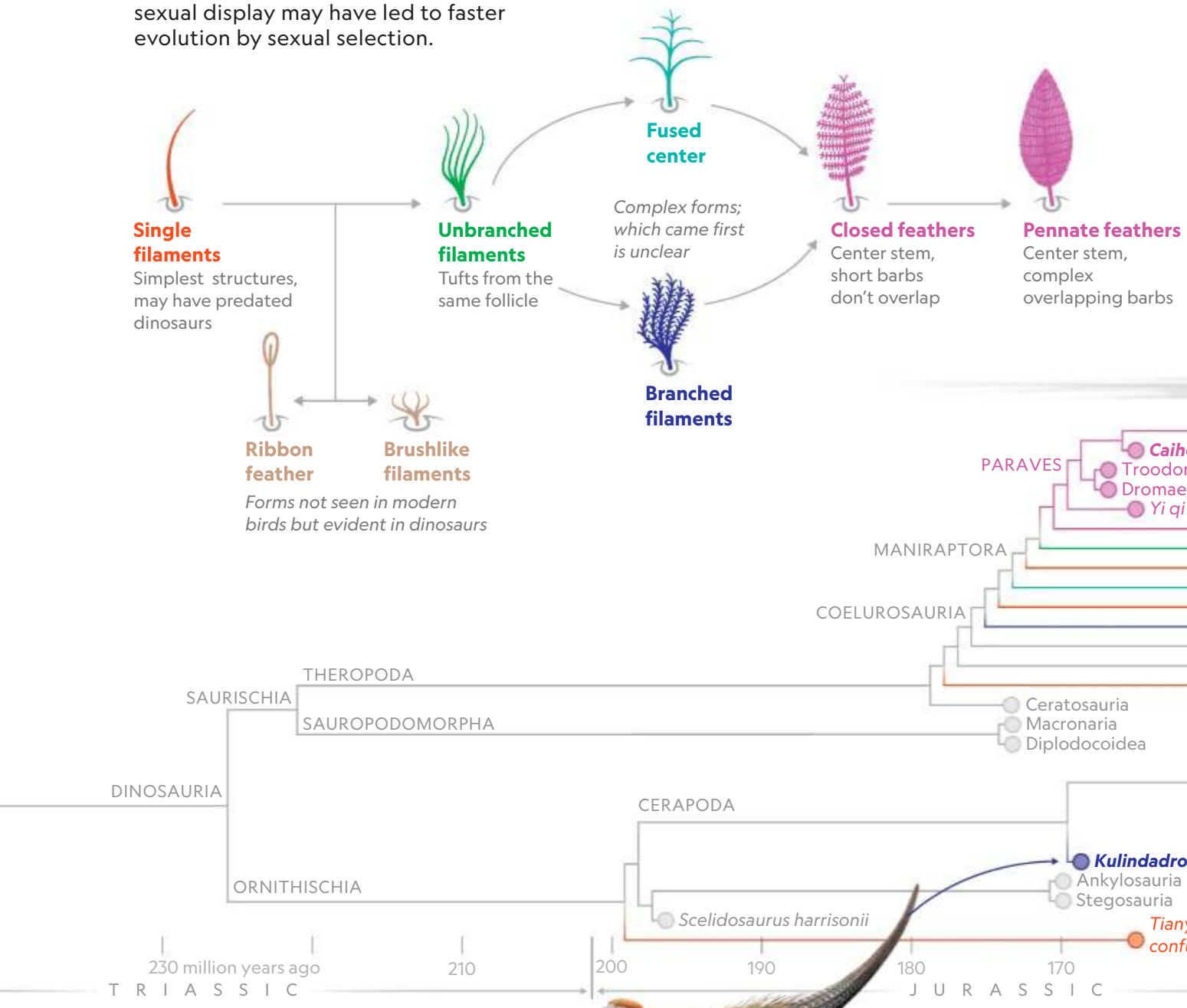
HOW THEY LOOKED

HOW THEY LOOKED

RESURRECTED IN COLOR

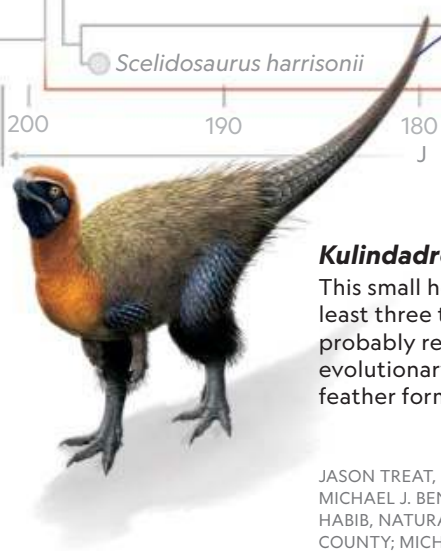
EVOLUTION OF FEATHERS

Fossils indicate that the first closed feathers (see below) evolved in the clade Maniraptora, along with the first color patterns in a single feather. The explosion of visual possibility for sexual display may have led to faster evolution by sexual selection.



FEATHERY FUZZ

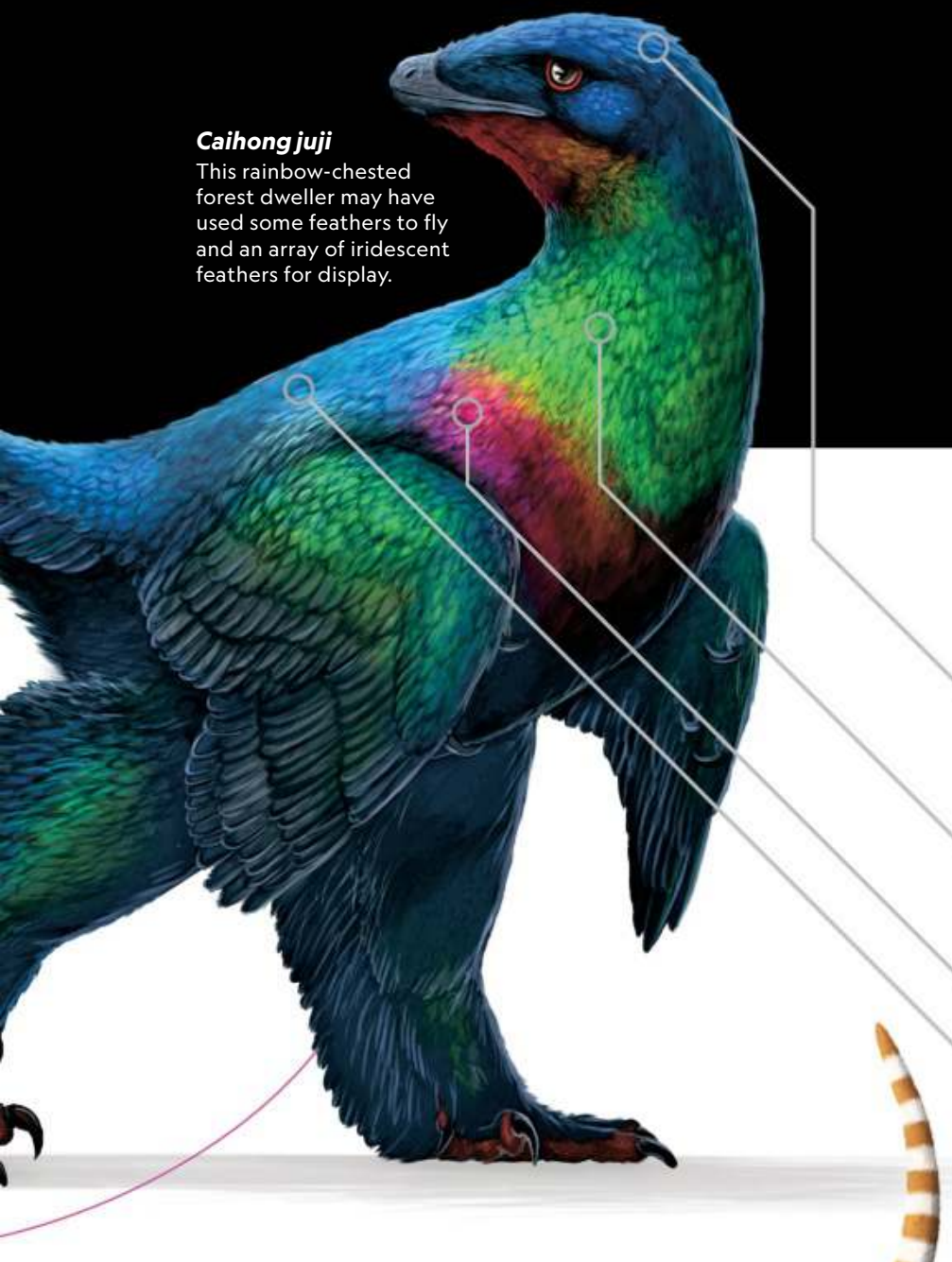
Many species had single-fiber feathers. The discovery of more complex feathers in species like *Kulindadromeus* implies that feathers originated and diversified early on, likely for insulation and display, not flight.



Kulindadromeus

This small herbivore had at least three types of feathers, probably representing various evolutionary experiments in feather form.

JASON TREAT, NGM STAFF; MESA SCHUMACHER. SOURCES: MICHAEL J. BENTON, UNIVERSITY OF BRISTOL; MICHAEL HABIB, NATURAL HISTORY MUSEUM OF LOS ANGELES COUNTY; MICHAEL PITTMAN, UNIVERSITY OF HONG KONG



Caihong juji
This rainbow-chested forest dweller may have used some feathers to fly and an array of iridescent feathers for display.

HOW OUR THINKING HAS CHANGED

Dinosaurs resembled reptiles in most early reconstructions. But scientists have been surprised to find that the genes leading to teeth, scales, hair, and feathers are closely related, making these features easy to swap over time. The result: a wide variety of feather and scale patterns as dinosaurs evolved.

MODERN RELATIVES

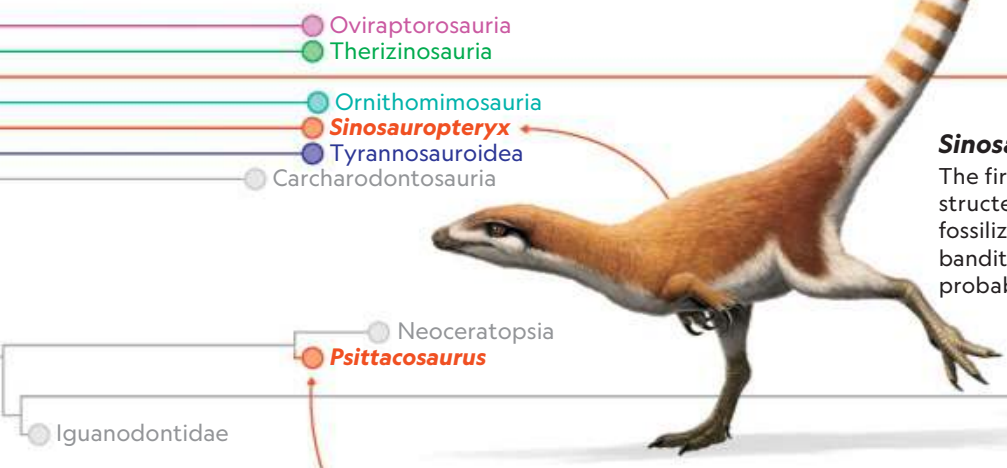
Melanosomes—cellular structures that contain the pigment melanin—help give feathers their color. By comparing their shape and arrangement in fossils with those in modern birds, experts can reconstruct a dinosaur's color and even see whether it was iridescent.

Crown feather
Moustached tree swift
Hemiprocne mystacea

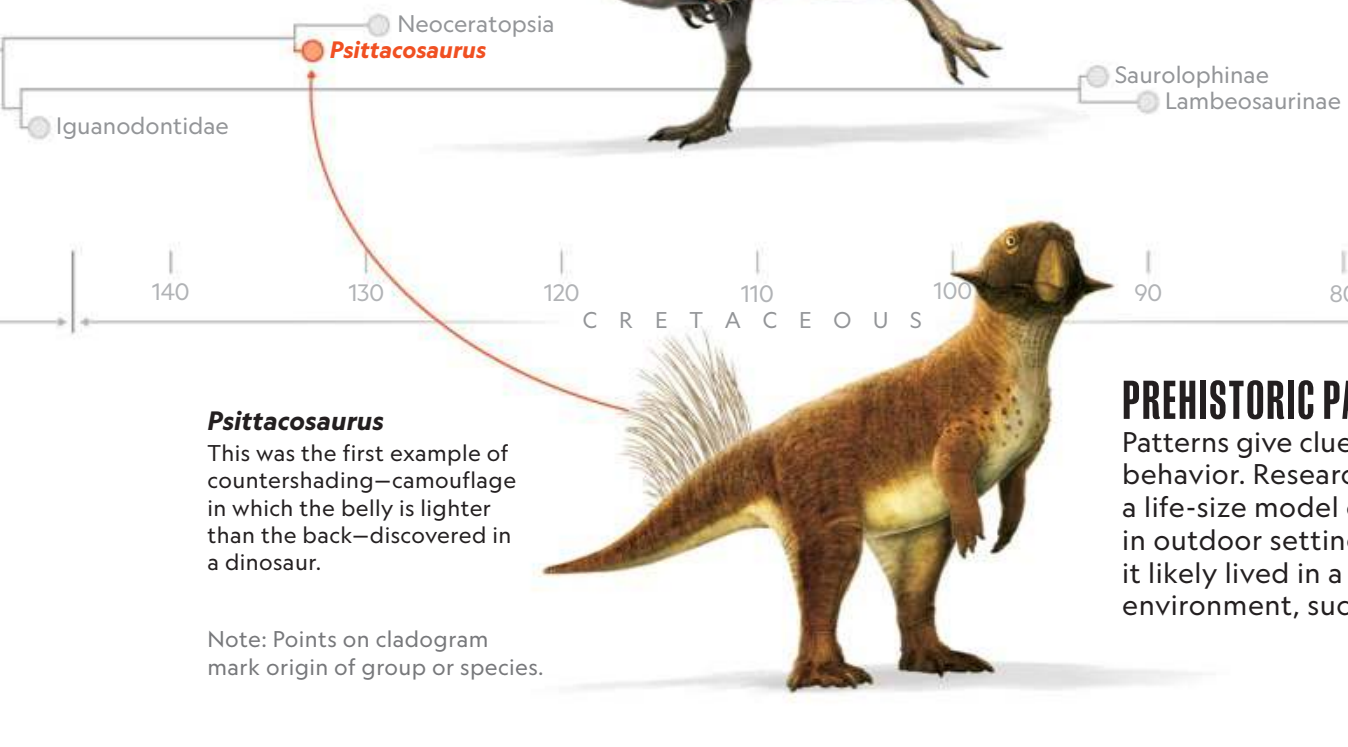
Neck feather
Anna's hummingbird
Calypte anna

Neck feather
Black-tailed trainbearer
Lesbia victoriae

Back feather
White-tailed starfrontlet
Coeligena phalerata



Sinosauropteryx
The first dinosaur reconstructed in color using fossilized melanosomes had a bandit face and a ringed tail, probably used for display.



Psittacosaurus
This was the first example of countershading—camouflage in which the belly is lighter than the back—discovered in a dinosaur.

Note: Points on cladogram mark origin of group or species.

PREHISTORIC PATTERNS

Patterns give clues to environment and behavior. Researchers photographed a life-size model of *Psittacosaurus* in outdoor settings and determined it likely lived in a varied-light environment, such as a forest.

Hesperornis (above), a Cretaceous proto-bird, is a distant relative of the early theropod *Coelophysis,* whose skull rests in the hands of Yale paleontologist Bhart-Anjan Bhullar. His research shows that as birds evolved, their adult skulls kept features that extinct dinosaurs had only as juveniles, paving the way for the avian beak.

PHOTOGRAPHED AT PEABODY MUSEUM OF NATURAL HISTORY, YALE UNIVERSITY

Advanced tools for examining fossil bones can resolve details less than a hundredth of the width of a human red blood cell.

Radiation Facility, which in recent years has become a mecca for paleontologists, thanks to staff researcher Paul Tafforeau.

The ESRF is a particle accelerator that flings electrons around at nearly the speed of light. As the electron beam makes its laps, magnets along the circular track bend the particle stream. The disruption makes the particles give off some of the world's most intense x-rays, which researchers often use to study new materials and medicines. Tafforeau specializes in using the x-rays to look inside fossils that typical CT scanners can't make sense of, at resolutions those scanners can't reach.

As we tour the accelerator's steel and concrete innards, I ask Tafforeau just how discerning the machine can get. He gestures to a display case, with 3D-printed examples of past fossils he's x-rayed. Portions of one of them, a burrow more than 250 million years old, were scanned finely enough to resolve details as narrow as a human red blood cell. When conditions are just right, Tafforeau's scans can show features less than a hundredth of that width. Such is the power of a magnifying glass the size of a football stadium.

With great power, though, comes great responsibility. To illustrate the importance of safety to new students, Tafforeau uses an unfiltered beam to light objects on fire and roast coffee beans. "Most of the beams we are using to scan fossils would kill you in just a few seconds," he says.

The ESRF's intensity has worked wonders for Dennis Voeten of Sweden's Uppsala University, who used it to virtually slice through *Archaeopteryx* fossils and trace out the cross sections of the bones in exacting detail. Because bones must withstand the strain of flight, their geometric structure can speak to the animals' flying styles. Though *Archaeopteryx*'s anatomy didn't allow for a fully birdlike flap, the cross sections of its wing bones most closely resemble those in living pheasants, which fly in short bursts. It's a striking hint at how the 150-million-year-old creature—an iconic snapshot of dinosaurs' evolution into birds—navigated the Jurassic island chains it may once have called home.

Kimi Chapelle of South Africa's University of the Witwatersrand has used the facility to look inside the world's oldest known dinosaur eggs, which belong to the southern African herbivore *Massospondylus*. The x-rays let her reconstruct the embryonic skulls inside, down to tiny teeth the dinosaur would have either shed or reabsorbed before hatching. Modern gecko embryos also have these prototeeth, despite the fact that geckos' and dinosaurs' last common ancestors lived more than a quarter billion years ago. Thanks in part to geckos, Chapelle figured out that the *Massospondylus* embryos made it three-fifths of the way through their incubation before dying—an intimate glimpse into lives cut short more than 200 million years ago. "That makes them feel much more real," she tells me.

EACH SPRING Beijing's Institute of Vertebrate Paleontology and Paleoanthropology welcomes its own symbol of life's ephemeral nature, as a blanket of cherry and plum blossoms unfurls across the Chinese capital. To Jingmai O'Connor, the scene is impossibly charming: Gargoyles sculpted in the likenesses of ancient fish, dinosaurs, and saber-toothed cats look out from the main building onto gaggles of laughing schoolchildren. "It's like paleontology Disneyland, almost," the IVPP researcher says.

On the inside, though, the IVPP is more time machine than theme park. Since the 1990s, farmers, researchers, and fossil dealers in northeastern China's Liaoning Province have brought in hundreds of fossils that have upended our understanding of how dinosaurs looked and behaved. Many preserve traces of feathers that confirm plumage first evolved before dinosaurs ever flew. Some fossils also reveal, in dramatic fashion, that dinosaurs other than birds' closest ancestors also tried defying gravity.

Few dinosaurs better reflect the constantly shifting picture than the scansoriopterygids (SCAN-soar-ee-OP-tuh-RIH-jidz), an obscure group of Jurassic dinosaurs with a mouthful of a name. Some scientists once thought that the crow-size animals used their four-inch-long fingers to nab bugs, like modern aye-ayes do.

Native to South America, the hoatzin offers clues to how dinosaur arms evolved into bird wings. Unique among living birds, hoatzin nestlings have dinosaur-like claws on their wings that they use to climb back into trees after dropping into water to escape predators.

PHOTOGRAPHED AT PEABODY MUSEUM OF NATURAL HISTORY, YALE UNIVERSITY

But in 2015, IVPP researchers unveiled a bizarre member of the group that turned out to be a lost dead end in the origins of flight. Unlike any other dinosaur ever found, *Yi qi* had batlike membranous wings that it supported with its long outer fingers and bony wrist spurs. "That's what the story is: One very important specimen ... really just kind of knocked everything that we thought we knew upside down," O'Connor says.

China's fossils, and others from equally remarkable sites around the world, preserve vestiges of all kinds of tissue. In 2014 researchers announced they had found an *Edmontosaurus regalis*, a type of hadrosaur, in western Canada that has a cockscomb of mummified flesh, like what you'd see on a rooster. This is a structure nobody knew the dinosaur had, despite knowing of the species for nearly a century. Dinosaurs' bones had shown that the creatures used exaggerated body parts to woo mates and jockey for social status, just like modern animals, or to find their kin. With *Edmontosaurus* and other dinosaurs bearing soft tissues, paleontologists are seeing hints of these displays' true splendor.

Fluorescing a ghostly blue, a stained chicken embryo in Bhullar's lab is in line to be examined under a microscope. By tracking how genes orchestrate the patterns of animals' growing bodies, Bhullar can see the nuts and bolts of development, improving our understanding of dinosaurs and their modern descendants.

In a few cases, researchers can even infer some of the animals' original chemistries. In 2008 scientists led by paleontologist Jakob Vinther, now of the U.K.'s University of Bristol, figured out that melanosomes, tiny subcellular sacs filled with the pigment melanin, could fossilize. The discovery opened the door to a field once thought impossible: figuring out the colors of extinct dinosaurs' skin and feathers, based on the shapes, sizes, and arrangements of their melanosomes.

These reconstructions come with caveats: Living animals employ other pigments besides melanin, and some extinct dinosaurs probably did too. Even so, recent finds have been astonishing. The feathered dinosaur *Anchiornis,* which lived in what is now China, had a reddish crest; the early ceratopsian *Psittacosaurus* had red-brown skin that contributed to an early form of dino camouflage. In 2018 an international team reported that the feathers of *Caihong*, a dinosaur that lived in the same region as *Yi qi*, once shimmered with all the colors of the rainbow.

Even more of life's molecules may last through deep time. In the 2000s, North Carolina State University paleontologist Mary Schweitzer made waves when she found that some dinosaur fossils, including *T. rex* specimens, contained preserved cells, blood vessels, and maybe even vestiges of proteins. Ever since, Schweitzer and a growing cohort of scientists have asked how such substances could persist—and what we could learn from them.

At her lab in New Haven, Connecticut, Yale Ph.D. candidate Jasmina Wiemann shows me how she grinds up a small piece of *Allosaurus* bone for analysis. She transfers the dust into a tube and invites me to add an acid solution, which fizzes and turns a deep brown. "It reminds me always a little bit of Coca-Cola," she says. Under a microscope, the gunk left behind includes spongy mahogany chunks shot through with black squiggles. I can't believe what I'm seeing. The brown schmutz was once protein-rich tissue. The squiggles? The outlines of bone cells that lived more than 145 million years ago in a toothy Jurassic predator as long as a school bus. After millions of years, heat and pressure often will transform these kinds of microscopic remains through chemical reactions. Despite their altered state, the materials hold invaluable clues to dinosaur behavior. In a 2018 study Wiemann showed that when certain dinosaur

05

Two *Edmontosaurus* bulls fight over a mate. Large hadrosaurs may have been socially complex, communicating via low rumbling sounds.

SOURCES: DAVID C. EVANS, ROYAL ONTARIO MUSEUM; PHIL BELL, UNIVERSITY OF NEW ENGLAND

WHAT'S NEW

Advances in 3D technology allow researchers to reconstruct detailed dinosaur anatomy, including inner ears, brain regions, and other soft-tissue structures. This is shedding new light on the mental and sensory abilities of dinosaurs and their capacity for social behavior.

HOW THEY

SOCIALIZED

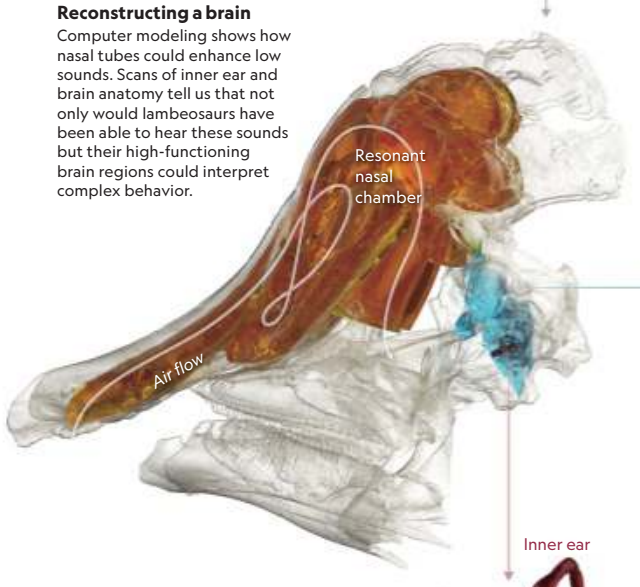
HOW THEY SOCIALIZED

DINO BRAINS

CONSTRUCTIVE CRESTS

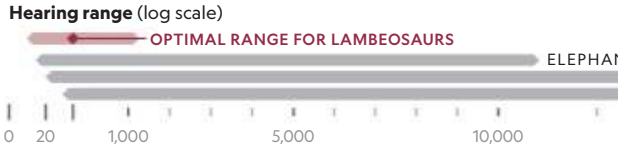
Studies of the inner ear of lambeosaurs find that they were the right size to have heard frequencies created by the nasal cavities in this group's crests. This supports the hypothesis that the crests were used for making sounds, as opposed to disproved theories including that they worked like snorkels for underwater dives.

Reconstructing a brain
Computer modeling shows how nasal tubes could enhance low sounds. Scans of inner ear and brain anatomy tell us that not only would lambeosaurs have been able to hear these sounds but their high-functioning brain regions could interpret complex behavior.



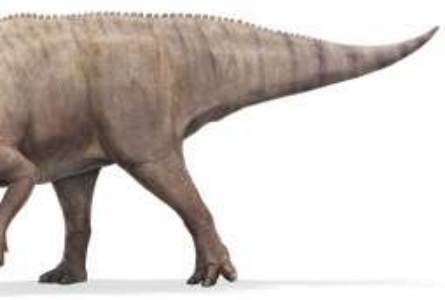
How they heard
In birds, the length of the basilar papilla—part of the cochlea—correlates with the range of frequencies they can best hear. With that clue, experts think dinosaurs heard lower frequencies best.

Hearing range (log scale)

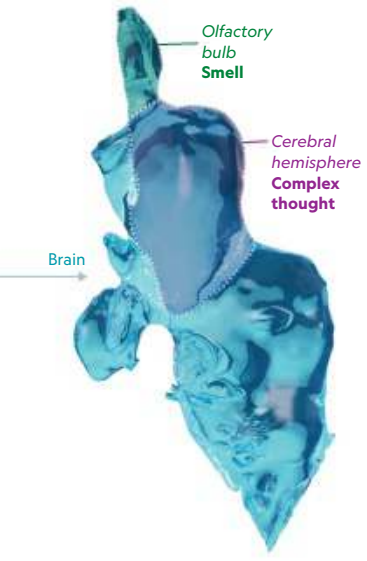


JASON TREAT, NGM STAFF; MESA SCHUMACHER. 3D RENDERING: SINELAB. SOURCES: LAWRENCE WITMER AND RYAN RIDGELY, OHIO UNIVERSITY; DAVID C. EVANS, ROYAL ONTARIO MUSEUM

HOW OUR THINKING HAS CHANGED
Scientists long wondered what purpose the bizarre, bony crests of lambeosaurs served. It was once thought the convoluted nasal passages enhanced smell; it's now believed the crests were a vocalization instrument similar to the elongated trachea of today's trumpeter swans.



Hypacrosaurus



Good at complex behavior
Brain scans found cerebral hemispheres involved in higher-level processing, such as interpreting social cues, made up over 40 percent of the lambeosaur's brain—more than nearly all other dinosaurs.

eggshells are struck with a laser, the light that scatters back reveals degraded protoporphyrin and biliverdin, compounds that give modern bird eggs color and speckling.

Based on such analysis, the calcified eggs of the *Velociraptor* relative *Deinonychus* had a bluish hue, suggesting that like modern birds with similarly colorful eggs, the dinosaur had open-air nests and brooded its young. By contrast, fossilized *Protoceratops* embryos found in Mongolia and *Mussaurus* embryos from Patagonia are surrounded by what was once leathery eggshell, according to a study Wiemann coauthored this year. The find suggests not only that these dinosaurs buried their nests like modern sea turtles do, but also that the first dinosaurs' eggs were similarly soft. That adds a twist to dinosaurs' evolutionary story, since it implies hard eggshells—which are found throughout the group Dinosauria—must not have a common origin. Instead, the trait evolved at least three times.

MORE THAN anything else, scientific advances show us that dinosaurs weren't the one-note menaces we sometimes see in popular culture. They courted each other with elaborate displays and squabbled for social status. They suffered broken bones and infections. They snapped after bugs and nibbled on ferns. Their days were as rich and varied, frenzied and humdrum, as those of the birds outside our windows. Even the biggest, baddest *T. rex* sometimes took a nap.

It's a realization that hits me as I walk through the lab of Yale assistant professor Bhart-Anjan Bhullar, whose cramped office is just down the hall from Wiemann's. Bhullar might work in a geology department, but he's taken only three geology classes in his life. He studies fossils and the embryos of living animals to try to unlock how ancient dinosaurs begot birds.

If anyone could genetically tweak a bird and make a chickensaurus, it's probably Bhullar. In one 2012 study he found that bird skulls are riffs on ancient dinosaurs' juvenile skulls, developmentally speaking: Young dinosaur skulls had thinner bones and more flexibility, which birds leveraged to evolve beaks. Parts of the old tool kit survived. Bhullar also has shown that blocking the beak's key molecular pathways can give chicken embryos *Archaeopteryx*-like snouts.

A microscope image of a quail embryo's forelimb looks exactly like the arm of a raptor dinosaur, down to the muscle and cartilage.

Across the avian body plan, Bhullar has found other striking examples of how bird embryos essentially summarize their own evolutionary history. He shows me a microscope image of a quail embryo's forelimb, which looks exactly like the arm of a raptor dinosaur, down to its tiny dinosaurian hand. "That's *Deinonychus*! Look at that!" Bhullar exclaims as he points to his laptop. Only closer to hatching is this ancestral form overwritten to become the familiar avian wing.

Long after I leave Yale I can't get that little quail claw out of my head. After years of reporting on extinct dinosaurs, I've grown dangerously accustomed to thinking about them in the past tense. But they are still with us, as ghosts within the eggs of their avian descendants.

The links between past and present get clearer in London, as our time on Dinosaur Island draws to a close. While the dinosaurs' world ended in a flash, the Crystal Palace dinosaurs face a slower, more creeping threat. The sculptures have been added to the U.K.'s registry of at-risk heritage, but a lack of upkeep has let cracks splinter through many of their discolored exteriors. In May part of the face broke off the island's *Megalosaurus,* damage caused either by deterioration or possibly by vandals. Conservation efforts are being planned, led by Friends of Crystal Palace Dinosaurs.

With the need for renewal all around us, I ask Maidment how today's scientists would build their version of Crystal Palace Park. Maidment offers an elegant answer: She'd fill it with birds. "Dinosaurs are the most diverse terrestrial vertebrates alive today, you know," she says, as a flock of gulls glides overhead and splashes down into the waters beyond. "They never stopped." ▯

Michael Greshko reported on a Canadian dinosaur fossil in the June 2017 issue. **Paolo Verzone** has won three World Press Photo awards. Scientific illustrator **Davide Bonadonna** first depicted *Spinosaurus* in the October 2014 issue. **Gabriel Ugueto** specializes in reconstructing extinct life.

BY **YUDHIJIT BHATTACHARJEE**

PHOTOGRAPHS BY **SMITA SHARMA**

STOLEN LIVES

SEX TRAFFICKING IS A WORLDWIDE SCOURGE,
ENSNARING MILLIONS OF CHILDREN.
THIS IS HOW TWO GIRLS WITH DREAMS—
ONE FROM INDIA, THE OTHER FROM BANGLADESH—
WERE FORCED INTO PROSTITUTION.

About this story: To protect the privacy of the girls who were trafficked and to comply with Indian laws on identifying victims of sexual crimes, we are not disclosing their identities or those of their family members. We photographed them in ways intended to obscure their faces and altered some images to hide distinguishing features. We use pseudonyms for the two girls featured in the story.

After a fight with her mother, R. left her home near Kolkata, one of India's largest cities. At a train station, she met some men who tricked her and took her to a red-light district in the city. Many girls who are trafficked in their teens spend the rest of their lives in brothels. R. was rescued before she was sold to one. She was sent to Sneha, a shelter run by a nonprofit called Sanlaap, which prepares victims to rebuild their lives. R., who is now an adult, and some of the other girls in this story were photographed at Sneha.

Anjali was 16 when she became involved with a man who enticed her to run away from her home in India's West Bengal state with the promise of marriage. Instead, he and an accomplice sold her to a brothel in Mahishadal, near Haldia, an industrial town. She was forced to have sex up to 20 times a day until she was rescued. For more than a year, she lived at Sneha among girls she said understood her anguish. Now an adult, she's living at home with her mother, who would like her to marry, but Anjali vows not to fall in love again.

When she was 12, S. left her home in Narayanganj, Bangladesh, with a family acquaintance who promised to find her a job in Dhaka. She was handed over to a man who trafficked her to West Bengal, then sold her to a brothel in Mumbai. S. was enslaved for two years before police freed her and sent her to a shelter. Six months later she met a woman who said she'd bring S. back to Bangladesh but instead sold her to a brothel in Namkhana in West Bengal. S. was rescued again and taken to Sneha. She's now an adult.

Before they were sold to the same brothel, Sayeda and Anjali were typical teenagers, growing up in similar circumstances a few hundred miles apart: Sayeda in the city of Khulna in Bangladesh, and Anjali in Siliguri in West Bengal, India.

They nurtured the aspirations of teenagers everywhere—to get out from under their parents, to find love, to start living out their dreams. Both were naive about the world and couldn't have imagined the cruelties it had in store.

Raised in a tiny two-room house in a squalid neighborhood, Sayeda spent much of her childhood on her own. Her mother would rise early and leave for the day to clean shops in New Market, one of Khulna's commercial districts. Sayeda's father was a cycle-rickshaw driver, ferrying passengers for a pittance. A struggling student, Sayeda dropped out of school before her teens, despite her mother's admonishments that trouble would befall her.

Outgoing and free-spirited, Sayeda was quick to smile and made friends easily. What she loved most was to dance. When her parents were out,

M., who is now 18, waits with her cousin for a train in South 24 Parganas, a largely poor district in West Bengal with a high incidence of trafficking. A man M. met in a class sold her to a brothel in Delhi. She managed to call her father and was rescued by police with help from a nonprofit called Shakti Vahini.

she would watch dance sequences from Hindi and Bengali movies on television, copying the moves. Sometimes, when her mother caught her, she would scold Sayeda. "Our neighbors didn't like that she was always singing and dancing," her mother told me.

Sayeda was beautiful, with a delicately chiseled face and almond-shaped eyes, and liked wearing makeup. She began to help out at beauty salons, learning about hairstyles, skin treatments, and cosmetics. Worried about the attention she was attracting from boys, her parents married her off when she was 13. Child marriage is common though illegal in much of South Asia. The husband Sayeda's parents chose was abusive, and she went back to her family.

When Sayeda returned home, she implored her mother to let her enroll in a dance academy. "I'll be able to perform in shows and make some money," she said. Her mother relented, and Sayeda began dancing at weddings and other events. That's when Sayeda became romantically involved with a boy who used to visit the academy. He told her he would take her to India, where she could earn a lot more as a dancer. Sayeda, imagining a future filled with promise, decided to run away with him.

Anjali, a graceful girl with bright eyes and high cheekbones, had similar reasons for wanting to leave home. Her family lived in a slum, in a makeshift dwelling. Raised primarily by her mother, who worked as a maid, she and her sister were so poor they fought over the few school supplies they could afford. By 13, Anjali had dropped out of school—the norm for many children from poor families across India. She

started working at a factory, packaging snacks. Reserved by nature, Anjali didn't have many friends. At home, her confidant was a baby goat she'd adopted, which followed her around, nibbling at her food during mealtimes and climbing into bed with her at night.

At the factory, Anjali met a young man who charmed her. Anjali knew her mother was on the lookout for a prospective groom for her, but she decided she wanted to be with the man she'd come to like. So, one evening in October 2016, during Durga Puja, a Hindu festival, Anjali put on a bright new *salwar kameez,* slipped out of the house, and took a bus to a train station to meet up with her boyfriend. To Anjali's surprise, he was with another young man, but she boarded a train to Kolkata with them.

Searching frantically for Anjali that evening, her mother gathered that she'd been planning to elope for some time. In the days before Anjali disappeared, the neighbors had heard her speaking to her goat, saying: "Who is going to take care of you when I'm gone?"

One estimate suggested that 50,000 girls are trafficked from Bangladesh to India each year.

OF ALL THE DEPRAVITIES that afflict humankind, among the most shocking is the enslavement of children for sexual gratification. Sayeda and Anjali, who told their stories to me, are just two of countless victims. As with most criminal enterprises, determining the scale of this atrocity is impossible, but it's clear that sex trafficking of minors is a multibillion-dollar industry that spans the globe.

According to a frequently cited study by the International Labour Organization, more than a million children were victims of sexual exploitation in 2016. Because detecting child prostitution is difficult, the report conceded that the actual number was likely far higher. The most recent Global Report on Trafficking in Persons, issued by the United Nations Office on Drugs and Crime, found that the number of victims of trafficking reported by countries rose from fewer than 15,000 in 2010 to nearly 25,000 in 2016. The statistics represent only a fraction of the actual victims; most are never detected. The increase may reflect improved enforcement, but researchers believe it more likely reflects a grimmer reality—that human trafficking, including the trafficking of children for prostitution, is on the rise.

"This is a growth industry," says Louise Shelley, a professor of public policy at George Mason University and author of *Human Trafficking: A Global Perspective.*

The scourge of child sex trafficking has left virtually no country untouched, but some parts of the world have emerged as hubs of this illicit trade. One that has been especially ravaged is the region where Sayeda and Anjali grew up—the Indian state of West Bengal and its neighbor Bangladesh, which once were a single province known as Bengal. Divided by a 1,400-mile international border but bound by a common cultural and linguistic heritage, the two areas share the misfortune of seeing thousands of girls sold into sexual slavery every year.

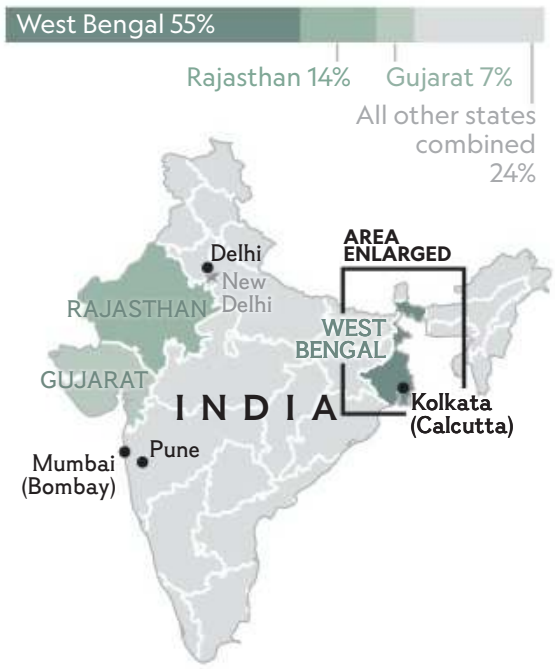
The actual toll is unknown, but numbers reported or estimated, however imperfect, point to a high volume of trafficking. According to India's National Crime Records Bureau, West Bengal accounted for almost a quarter of the 34,908 cases of human trafficking reported in the country from 2010 to 2016, a staggeringly large share for a state that makes up about 7 percent of the country's population. In 2017 alone, 8,178 children were reported missing from West Bengal, nearly an eighth of India's total that year. A significant number of girls among them were almost certainly sold to brothels. The picture might be worse for Bangladesh: One government estimate suggested 50,000 girls are trafficked out of the country to India, or through India, every year—a figure that doesn't include girls sold into prostitution within Bangladesh.

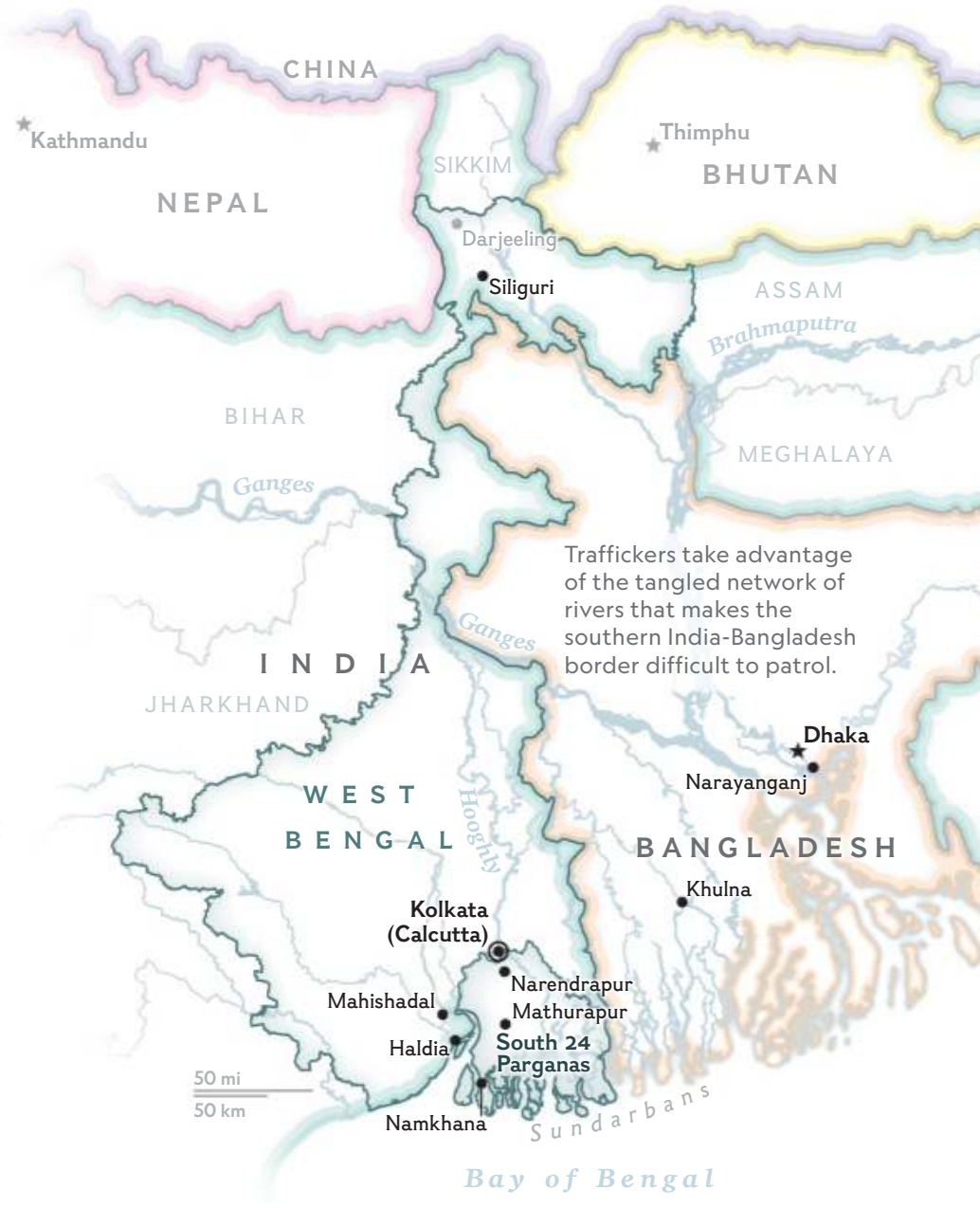
West Bengal is as much a destination as a source for girls who are trafficked into prostitution. The long border with Bangladesh and the 60 miles adjacent to Nepal include many unguarded stretches, allowing traffickers to smuggle girls into the state. Some end up in the red-light districts of Kolkata, a metropolis of more than 14 million people. Others are sold to brothels elsewhere in India—Delhi, Mumbai, Pune—or in the Middle East. (In India, commercial sex work is legal, but many activities

A Hidden Crime

The full scope of human trafficking in India—and around the world—is unclear. But in 2016, 4,911 girls were listed as trafficked by India's National Crime Records Bureau. More than half of those girls were from West Bengal, which has about 7 percent of India's population. Many cases are never reported.

Share of girls trafficked in 2016, by state





associated with the trade, such as pimping or running a brothel, are illegal, as is engaging children in prostitution.)

Not surprisingly, the biggest cause of this tragedy is the poverty that's widespread in the region, including one of India's largest districts, South 24 Parganas, an underdeveloped area with rough roads, little industry, and farmlands prone to flooding during the monsoon season. Gangs prey on girls from poor families, exploiting their destitution and other vulnerabilities.

"If I am a trafficker … I'll have to find out if the girl is starving and desperate for a job or if she's interested in romance," says Tapoti Bhowmick of Sanlaap, a Kolkata-based nonprofit that helps victims of trafficking. For girls raised in poverty, the promise of simple luxuries such as cell phones and beauty products can have a hypnotizing effect. "They want the kind of life for themselves that they have seen in soap operas on television," she explains.

Bhowmick says teenage boys and young men working for trafficking groups sometimes arrange fake marriages and even live with the girls for a while. "If the boy has spent even 20,000 rupees to trap the girl, he'll be able to sell her for 70,000 rupees," she says. That's a substantial profit—about $650, as much as many factory workers make in five months.

In recent years anti-trafficking police teams in West Bengal and elsewhere have stepped up efforts to find and rescue girls sold to brothels, but they are overwhelmed. "Whenever children go missing, we have to make sure that the police immediately start an investigation," says Rishi Kant, a co-founder of Shakti Vahini, a nonprofit that has helped free hundreds of victims.

Sanlaap and other nonprofits run programs to rehabilitate the girls in the hope that they might be able to reunite with their families, overcome social stigma, and build decent lives for themselves. But Kant says that state governments need to do more to support rescued victims. "They should be able to live like you and me," he says. "They should be empowered."

The measures currently in place are the equivalent of using a hammer to raze a fortress: The scale on which trafficking occurs is so huge that the solution requires a far more substantive and sustained law enforcement response, perhaps

CHRISTINE FELLENZ AND IRENE BERMAN-VAPORIS, NGM STAFF. SOURCE: NATIONAL CRIME RECORDS BUREAU, GOVERNMENT OF INDIA


BLUE
LOVE
LOVE

A crowd in Kolkata celebrates Durga Puja, West Bengal's most popular religious festival. Observed over nine days, the Hindu holiday provides a chance for girls to mingle freely with boys. Traffickers are known to use the cover of these crowds and the relaxed atmosphere to identify and trap potential victims.

Sayeda's mother holds her daughter's favorite sari at home in Khulna, Bangladesh. Sayeda's father gave it to her on Eid al-Fitr, the Muslim holiday that marks the end of Ramadan. It was the last one her family celebrated together. At 14, Sayeda eloped with a boy who sold her to a brothel in Mahishadal. For three years, she was beaten and forced to have sex. Sayeda was rescued and sent to Sneha but never made it home.

through a national agency dedicated solely to investigating trafficking cases.

THE DAY SAYEDA LEFT HOME, the boy she eloped with took her by bus from Khulna to a town near the Indian border. Arriving at night, they walked through a forest until they got to a riverbank. The boyfriend bribed a policeman, and the two climbed into a boat that took them to the other side. They were in India.

They stayed in a house close to the river. There, Sayeda met another girl who also had been brought over from Bangladesh, and she became suspicious. Sayeda confronted her boyfriend, and he told her she was going to work in a brothel. When she refused, he said, "I'll kill you and dump you in the river."

Even if she could have escaped, Sayeda didn't know whom she could have turned to for help. She had entered India illegally, and she didn't see how she could go to the police. "I got so scared that I said OK," she said. "I said I'll work as a dancer, fine. But I won't do anything else."

The boy sold Sayeda to a brothel in Mahishadal, a suburb of Haldia, a major river port and industrial city in West Bengal about 40 miles southwest of Kolkata. A dozen girls held captive at this brothel, including Sayeda and Anjali, talked to me. This account is based on those interviews. All the girls told similar stories of their captivity.

One in a row of such establishments along a highway, the brothel was a two-story hotel named Sankalpa with about 24 small rooms and a dance bar located behind a restaurant. According to the girls, it was run by a man named

Prasanta Bhakta. He could not be reached, and his lawyer declined to comment.

Sayeda, then 14, had believed she would be able to get away with only dancing for customers. She told me Bhakta disabused her of that notion right away by raping her. Sayeda learned from the other girls that this was his way of assessing what he could charge his customers for having sex with them. New arrivals like Sayeda—deemed closest to virginhood—were the most expensive: 500 rupees, or about seven dollars.

The girls said Bhakta forced them to drink alcohol, to make them more pliable. Although Sayeda was resistant, she discovered that being intoxicated helped blunt the trauma of being a sex slave. She began drinking heavily. "That's how I would pass the time—by drinking a lot through the day," she said.

Sayeda had been there for two years when Anjali, 16 at the time, was sold to the brothel. The man Anjali had expected to marry and the other young man had taken her to Kolkata and then to Mahishadal. The boyfriend's companion bought her soap, shampoo, a comb, and some makeup. He told her to freshen up, saying he was taking her to meet someone that evening.

Anjali didn't question them. When they entered a dimly lit room, she started to feel anxious. "What is this place?" she asked. They told her it was a hotel, and she would be working there. "What kind of work?" Anjali asked, starting to panic. When they explained it to her, tears welled in her eyes.

It was clear to Anjali from the first day that resistance was futile. The girls told me they were terrified of Bhakta, saying that he beat them savagely or burned them with his cigarette if they didn't obey him.

For the girls, the brothel was a prison. The gate in the fence around the building and the front door were always locked or guarded. The girls were allowed to leave only at midnight to eat at the restaurant in front, escorted by an elderly guard. He would make up nicknames for the girls and joke with them, bringing a touch of kindness to the grim reality of their lives.

The girls took painkillers to endure the physical torment. The emotional suffering was inescapable.

Customers came in day and night, and the girls were raped up to 20 times a day. They took painkillers to endure the physical torment, but the emotional suffering was inescapable. "We would feel such shame," Anjali said, "when we had customers who were older men, older than our fathers."

Bound by the trauma of having been trafficked and the daily horror of their brutal existence, the girls turned to each other for support. Anjali, quiet and shy, couldn't have been more different from Sayeda, who was so feisty when drunk that she sometimes kicked clients. Despite the

A West Bengal police boat patrols the Hooghly River in the Sundarbans, a watery area with dense mangrove forests that straddles the southern India-Bangladesh border. Traffickers often use rivers to avoid detection when smuggling girls into India.

Sisters Z. and B., now both adults, were trafficked by a relative when they were in their early teens from Dhaka to a brothel in Mahishadal. B. got pregnant at 15 and was forced to have an abortion. She often refused to have sex, and the owner would make her sister whip her with a belt. “This was the most painful,” Z. said, worse than having to have sex with 20 clients a day.

WHAT IS AVAXHOME?

AVAXHOME-

the biggest Internet portal, providing you various content: brand new books, trending movies, fresh magazines, hot games, recent software, latest music releases.

Unlimited satisfaction one low price
Cheap constant access to piping hot media
Protect your downloadings from Big brother
Safer, than torrent-trackers

18 years of seamless operation and our users' satisfaction

All languages
Brand new content
One site

AVXLIVE.ICU

AvaxHome - Your End Place

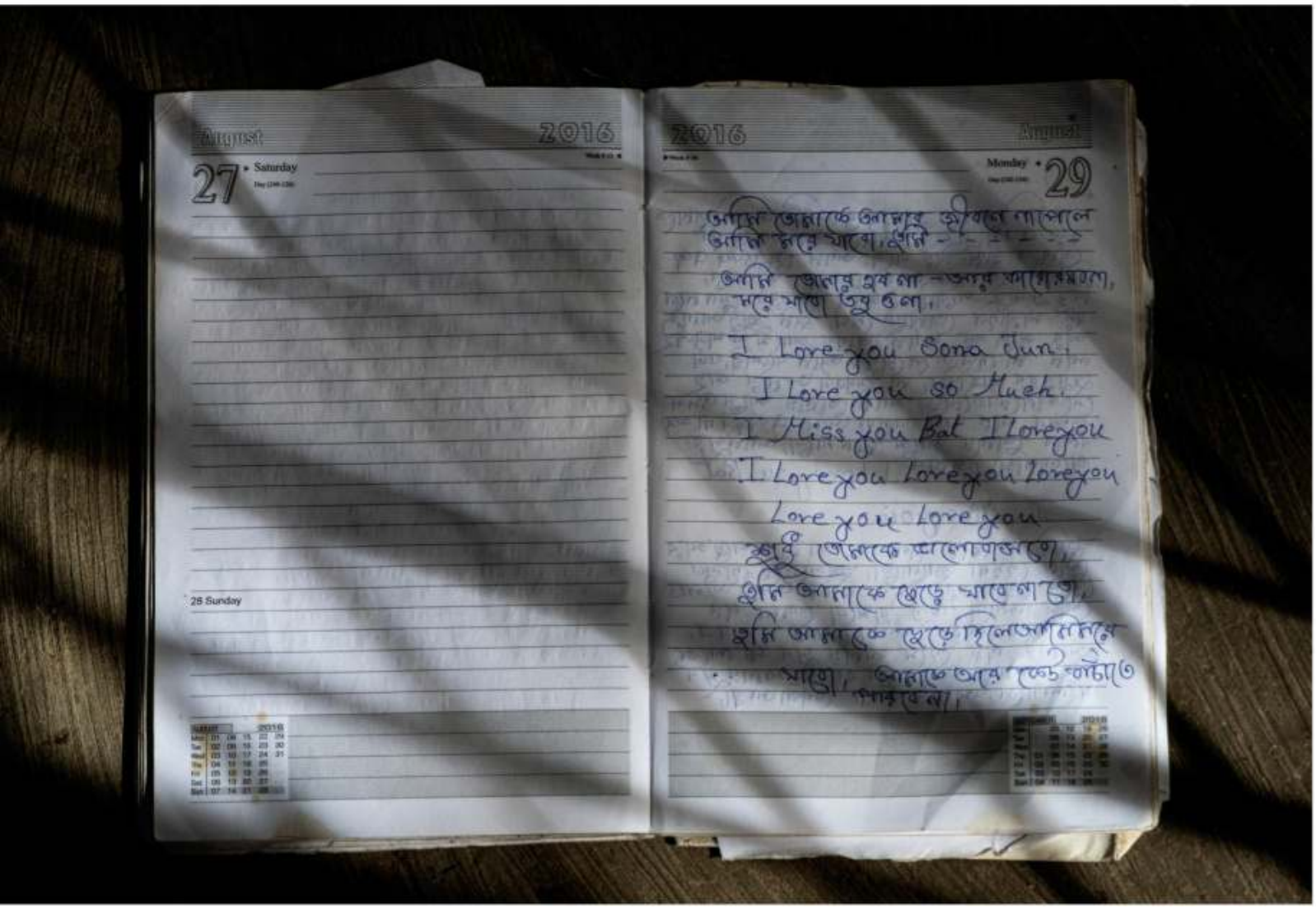
We have everything for all of your needs. Just open https://avxlive.icu

RIGHT

C., now a young adult, is comforted by her mother after being reunited with her family in South 24 Parganas. From passages in her diary, the family realized she'd eloped with a man she'd met. Months later, police rescued her from a brothel in Pune.

BELOW

C.'s diary offers a glimpse into the teenager's infatuation, which the man who trafficked her exploited. Her words in Bengali say: "If I don't get you in my life, I will die. If I am not yours, I can't be anyone else's."



contrast in personalities, or perhaps because of it, the two became friends.

Once in a while there would be a police raid, but the girls said Bhakta and his staff always seemed to have advance warning. They would hustle the girls out the back before the cops arrived. One afternoon in April 2017, though, a police team raided the brothel and another next door, without Bhakta's being tipped off. The police arrested him and 12 others under laws that prohibit trafficking and sexual exploitation of children. Anjali and Sayeda, along with 18 other girls and women, were rescued. They were free but not yet free to go home.

SAYEDA AND ANJALI were 17 when I met them at Sneha, a shelter run by Sanlaap in Narendrapur, a suburb of Kolkata—the metropolis where I once was a crime reporter. They had arrived just days before, along with 10 other girls rescued from Mahishadal. All of them agreed to meet with me.

A supervisor ushered them into a large unfurnished room where I was waiting with a representative from Sanlaap. Slipping their footwear off, they filed in, pausing their chatter as they took me in with guarded glances. The awkwardness eased after I joined them in unrolling a large rug. We sat down in a circle. As we began conversing in Bengali—the language I grew up speaking at home—the girls became more comfortable.

Sayeda, seated to my right, was the keenest to talk. She had an easy confidence that set her apart. When I asked how she'd ended up at the brothel, she told me matter-of-factly that she'd been tricked by the boy she loved. She described how the staff kept a strict watch on the girls and how the brothel owner, Bhakta, routinely beat her and the others.

"He wouldn't stop until he drew blood," Anjali, sitting next to Sayeda, interjected.

"He used to tell us—if you don't sleep with at least 10 customers a day, I'll beat you," Sayeda said.

I turned to Anjali, who told me how she'd been trafficked by her boyfriend. "He told me he would marry me," she said, smiling abashedly. The other girls laughed. It felt like they were being unkind, but over the course of our conversations, I realized they hadn't been laughing at Anjali as much as laughing with her. Their stories were similar. The longer I spent talking with the girls, the more I realized the impossibility of comprehending the desperation they'd felt.

When I went back to the shelter the next morning, I asked whether Sayeda and Anjali would talk to me again, since they had been the most forthcoming. Sayeda showed up grinning ear to ear, her forehead and cheeks covered in colored powders: red, blue, green. It was just days after Holi, a Hindu holiday that people celebrate by splashing color on one another. I gathered that Sayeda had joyfully accepted a full smearing of her face from other girls at the shelter that morning. Anjali had gotten away with a minor dabbing.

The two told me of the horrors they'd experienced with a detachment that I found unnerving. Not sure how I could get her to describe her feelings about this abuse, I asked Sayeda how much she'd wept in the three years she'd been enslaved, realizing as soon as I said it how shallow it sounded. "Oh, I've cried and cried. How much more could I cry?" she replied in a tone of resignation I'd never heard from someone so young. The sum of her tears would never be enough to convey the measure of her sadness.

Farrak Ali Gayen, who was arrested in July 2017, stands between Jagdeep Singh Rawat, an anti-trafficking activist with Shakti Vahini, and police officer Shibendu Ghosh in the Mathurapur Police Station near Kolkata. Gayen said he was paid $260 for every girl he brought to his sister in Delhi and that she sold the girls to brothels. He said he and others on his team trafficked 11 girls from South 24 Parganas over a year and a half. His sister and others were also arrested. The case is ongoing.

I asked them what they would do when they returned home. Anjali was unsure.

"Will you fall in love again?" Sayeda asked, laughing.

"No, I will not," Anjali replied.

Sayeda said she would try to get a job at the beauty parlor where she'd worked. "I won't go back to dancing. I'll try to get an education."

"I might take dance lessons," Anjali said.

"No, don't get into dancing," Sayeda warned. "That could lead to trouble."

As we came out of the building into the sun, Sayeda asked me if I could use my cell phone to find a satellite view of her city. She wanted to show me the neighborhood where her parents lived, next to a well-known mosque. I couldn't do that on my phone, but I promised I would visit her in Khulna when she returned to her family.

Smiling, she ran over to a play area in front of the building. I watched her climb to the top of a slide and glide down. Walking toward my car, I could hear her laughing.

ONE AFTERNOON two years ago Giriraj Panda, a lawyer in Haldia who has helped prosecute sex trafficking cases, was eating lunch at a food shack near the courthouse when a sudden commotion disrupted the usual thrum of activity. Panda looked up and saw a man racing away, chased by a couple of policemen. The cops were too slow. The man outran them and climbed on a motorbike driven by an accomplice. The two sped away.

Panda, hired by Sanlaap to represent the girls in the case against Bhakta and the others, recognized the fleeing man. It was Bhakta. He was due in court when he managed to break free from the

officers leading him into the building with his hands clasped in theirs. Bhakta had appeared in court before on similar charges, Panda said, but his lawyers had been able to arrange his release on bail. Apparently, Bhakta was risking a daring escape because he hadn't managed to get out on these new charges. He'd been in jail for more than a year and a half.

Brothel owners and traffickers who exploit minors are often able to get away with their crimes not just because the police fail to enforce the law but also because India's judicial system leaves open many avenues of escape. Indian courts are inundated with cases, and the backlog is so huge that it's not unusual for prosecutions to stretch over years. Sometimes courts have no choice but to grant bail to defendants because prosecutors fail to file charges on time, owing to incompetence or corruption.

Despite this grim state of affairs, efforts to bring traffickers to justice haven't been abandoned. In the past six years, Panda said, he and his team have secured convictions in more than a dozen trafficking cases in the Haldia area. He said he would fight to prove the charges against Bhakta, who Panda said was tracked down and arrested a few weeks after his escape.

The case is ongoing and could last for years. Bhakta did get bail earlier this year—a decision Panda said prosecutors will appeal. "Because traffickers and brothel owners can afford to spend a lot on legal fees, it's easy for them to get away," Panda said. "But we refuse to give up."

A FEW MONTHS after my visit to Sneha, Sayeda began suffering severe abdominal pains. Just days earlier, she'd performed enthusiastically in a dance show at the shelter. Sneha's staff rushed her to the hospital, where she died hours later. Doctors attributed Sayeda's death to liver failure, most likely caused by her heavy drinking.

Brothel owners and traffickers who exploit minors often are able to get away with their crimes.

In November 2018, I traveled to Khulna with photographer Smita Sharma to see Sayeda's family—a trip that Sayeda and I had imagined would be a happy one. Driving past the mosque that Sayeda had wanted to show me, we wended through the streets and parked next to a tea shop. Sayeda's mother—a short, stocky woman dressed in a salwar kameez—led us along a dirt path to the house where Sayeda had grown up. Her father, a slight, haggard man, greeted us feebly. Since the outer room had no furniture, they invited us into their bedroom. Smita and I sat cross-legged on the bed, the afternoon light pouring in through the window.

When Sayeda's mother described how much her daughter enjoyed singing and dancing, I showed her a photograph of Sayeda with Anjali and the other girls taken after their dance

Shiuli, a 27-year-old sex worker, arranges to meet a client in the Kalighat red-light district of Kolkata. Married at 13, Shiuli eventually left her husband, taking their son with her, but her parents wouldn't let her return home. She narrowly averted being trafficked. Unable to make enough as a maid, she became a sex worker. She has two other sons, fathered by clients.

performance. Wearing a bright magenta sari and a yellow crown, Sayeda is smiling radiantly.

Her mother looked at the photo for a moment and began to weep. "My daughter had such a simple, innocent heart," she said, wiping her tears. "That is why I lost her."

Sayeda's parents knew their daughter had been trafficked and enslaved in a brothel, but they wanted to know more about what she'd gone through, so I turned on a recording of my interview with Sayeda. Her mother leaned in to listen. Her father listened from the other room, where he sat on the floor, staring blankly at the wall. As Sayeda started talking about what she'd endured at the brothel, her mother shifted uncomfortably and her father turned his head away.

"Hearing this might hurt," I said.

Sayeda's mother looked at me, her eyes brimming. "We are hurting anyway," she said. "There's no end to the pain."

Her father didn't say a word that afternoon. When I returned the next day to say goodbye to the family, he finally spoke. Since Sayeda's death, he said, he'd become erratic, skipping meals and baths often, sitting by the roadside for long periods of time, transfixed by grief, instead of ferrying passengers in his rickshaw.

"My daughter was my world," he told me. "She used to be happy all the time and make others happy, and now she's gone."

'A person is only fooled once. Not again and again,' Anjali said. 'I don't love anybody anymore.'

AFTER A YEAR AND A HALF at the shelter, Anjali finally returned home to her mother in Siliguri and began working at a factory. When I visited in December 2019, Anjali, then 19, was helping her mother with household chores.

Anjali told me she struggles with loneliness. She misses her friends from the shelter, who understood her anguish as no one else ever will. She hadn't shared much of her experience with her mother. Anjali said she'd overheard some of the neighbors talking about her being in a dirty profession.

"I don't respond to them," she said.

It was evident that the neighbors' shaming had deepened Anjali's sense of isolation. She could pretend the neighbors didn't exist, but it was harder for her to tune out the words of her mother, who had become intensely protective, causing Anjali to feel stifled.

"She doesn't let me go out anywhere!" Anjali complained.

"I tell her, Sit quietly at home. Be on your phone. Watch TikTok videos if you like," her mother said. "Don't ever set foot on the wrong path again."

I asked what she meant. Wasn't Anjali the victim? Was it wrong to fall in love?

"Yes, I know she fell in love. But who could

Sex workers and staff members attend the annual anniversary event of New Light, a nonprofit located in Kalighat. The organization offers care and schooling for the children of sex workers. It also collaborates with the union that represents them to prevent brothels in the area from forcing children into prostitution.

HOW TO HELP

Here are three groups working in India on behalf of sex trafficking victims.

Shakti Vahini works to free minors from brothels: *shaktivahini.org*

Sanlaap aids girls who have been rescued or are at risk of being exploited: *sanlaap.org*

New Light helps the children of sex workers: *newlightindia.org*

have known that the boy had such evil intentions?" her mother said. "I mean that she's vulnerable. She's young. She could easily be lured by another boy who might promise to marry her and then go and sell her to another place, like it happened before."

"A person is only fooled once," Anjali said. "Not again and again, you know."

Her mother tried to mollify her. "I've been telling her, Don't elope," she said. "If you find somebody you like, tell me, and I'll check out the boy's background and get you married."

Anjali cut her off. "I don't love anybody anymore," she said in a tone of finality.

What she really wanted, she told me, was to be able to go wherever she wanted whenever she wanted. Anjali wanted a scooter. She wasn't happy that her mother was saving up to buy Anjali's older brother a motorcycle.

"I'll buy you things when you get married," her mother said gently.

Anjali gave her an exasperated smile. Despite her annoyance, she knew she was a lot more fortunate than many trafficking victims whose families don't want them back because of the fear of being shamed by relatives and neighbors. Anjali's struggle to rebuild her life was clearly far from over, yet seeing the support of her family and her quiet resolve, I left with the hope that she would someday find the freedom she has been seeking. □

Yudhijit Bhattacharjee is a contributing writer. He began his journalism career writing about crime in Kolkata. **Smita Sharma,** who is based in Delhi, has spent years documenting sexual violence in India. This is her first story for the magazine.

SAVING THE AMAZON'S GIANT RAPTORS

Scientists, Brazil nut collectors, landowners, and tourism hosts are joining forces to help conserve one of the world's largest eagles.

BY **RACHEL NUWER** PHOTOGRAPHS BY **KARINE AIGNER**

A harpy eagle guards her chick in a nest in Amazonian Brazil. Females are bigger than males and can weigh about 24 pounds, with claws often larger than a grizzly bear's. Since the 1800s, their range across Central and South America has declined by more than 40 percent.

Harpy eagles are now mainly found in the Amazon rainforest, where tree cutting for ranching is eating away at their habitat. Conservationists hope ranchers will limit clearing if they make enough money from tourists who pay to see eagles in their nests from towers such as this one.

It was supposed to be a shortcut. Now, waist-high in latte brown water, I find myself stumbling over submerged logs,

ducking under ant-teeming briars, and pushing through sticky curtains of spiderwebs—following a trail blazed by Brazilian biologist Everton Miranda. One expensive camera has already gone belly-up after field assistant Edson Oliveira face-planted into an engorged puddle, and a wasp sting on photographer Karine Aigner's forearm has ballooned into a welt the size and color of a plump tomato.

But if turning back is on anyone's mind, they keep the thought to themselves. Our mission is too important. We're here to find an elusive harpy eagle nest, rumored to be about a mile inside this patch of Amazon rainforest in Mato Grosso, a state more than three times the size of Arizona.

With their sleek, monochrome bodies, ferocious eyes, and exuberant facial feathers resembling avian pigtails, harpy eagles—one of the world's largest eagle species—often are ranked among the planet's most spectacular birds and at the top of many birders' lists. Their talons, capable of snatching a grown sloth from a tree, can be larger than a grizzly bear's claw, and females can weigh

These raptors have a relatively short wingspan, allowing them to navigate through the dense jungle. They can snatch a grown sloth from a tree and carry off a small deer. This harpy eagle is returning to its nest with the remains of a porcupine.

This story was created in partnership with the National Geographic Society and the Wyss Campaign for Nature, which seek to inspire the protection of 30 percent of the planet by 2030.

about 24 pounds. “They look like an animal from a fantasy book,” Miranda says.

As top predators, harpy eagles play a crucial ecological role, helping to keep populations of prey species in check. “If you achieve conservation for harpy eagles, then you achieve conservation for pretty much all biodiversity in the ecosystem they inhabit as well,” says Richard Watson, president and CEO of the Peregrine Fund, a nonprofit conservation organization that leads a harpy eagle program in Panama.

No one knows how many remain in the wild, but scientists do know that they’re disappearing. The powerful raptors once lived from southern Mexico to northern Argentina, but since the 1800s their range has shrunk by more than 40 percent and is now limited mostly to the Amazon, according to Miranda. Deforestation from farming, mining, and development—the primary threat to harpy eagles’ survival—shows no signs of slowing. Miranda calculated that 136 acres of jungle were razed every hour in the Brazilian Amazon in early 2020.

Miranda, a mixed martial arts fighter turned scientist, is at the forefront of efforts to save Brazil’s harpy eagles. He says he’s certain that without effective conservation, the raptors soon will disappear from a significant slice of their Brazilian stronghold—the so-called arc of deforestation, a fragmented landscape about the size of Spain encircling the southeastern Amazon like a crooked grin. He believes that rampant habitat loss can be combated by showing Brazilians that the forests are more

A freshly killed armadillo will be a meal for a hungry chick. Scientists are monitoring the nest as part of an effort to protect harpy eagles in areas most vulnerable to deforestation.

profitable standing than felled, and with that in mind, he recently helped launch an innovative ecotourism program to give landowners incentive to protect harpy eagles and their habitats. (Fortunately, the first two months of 2020 brought back-to-back bookings, the proceeds of which will keep the project going until the end of the year, when it's hoped that the pandemic's worst effects will have subsided and travel will have resumed.)

If we find the nest, it will add another crucial data point for identifying the kinds of places where harpy eagles still live and then protecting those places. Miranda glances at a GPS pin marking the spot where he believes the nest to be. A racing stream blocks our way. Undeterred, he locates a toppled, half-rotten log, which miraculously holds our weight as we take turns scooching across. Scrambling up a muddy embankment, now finally on solid ground, we zip through the last half mile until we spot the wide, stately trunk of a Brazil nut tree. The towering canopy branches of this protected species

Harpy eagles like to nest in the towering canopy of Brazil nut trees. That's why nut collectors have become key to finding the rare nests.

are the choice nesting spot for harpy eagles in Miranda's study area. We peer into the thick foliage above. About a hundred feet up, a peephole reveals a giant mass of twigs. The nest!

But other than one slender, white feather spotted by Miranda, we find no other evidence the nest is occupied. Playback of recorded harpy eagle calls—a piercing series of screeches—also fails to elicit any replies. Miranda guesses that the chick that formerly occupied this nest full-time must be an adolescent, in the process of leaving after her three-year time in her parents' home range.

Harpy eagles, if left undisturbed, may use a single nest for decades, and Miranda says this one likely will have a new resident chick toward the end of 2020. If all goes well, he hopes, tourists will be brought here to marvel at it—and to help protect it.

RATHER THAN STUDY harpy eagles in the unspoiled Amazon, Miranda chose to focus on the arc of deforestation because of the urgency of the threats there. From 2004 to 2012, Brazil reduced its deforestation rate by 83 percent, to 1,700 square miles a year. But forest clearing picked up again as cattle and soybean barons began buying influence with politicians. Jair Bolsonaro, who became president in 2019, scaled back efforts to curb illegal cutting, contributing to a 30 percent increase in deforestation. By some estimates, 95 percent of today's expanding deforestation is illegal.

When Miranda arrived in the region, people told him that harpy eagles already had disappeared. He based himself in a French research station about 160 miles west of Alta Floresta, a town with nearly 52,000 people and more than 790,000 cattle.

To begin his research, Miranda needed to find nests. After slogging through 30 miles of jungle, he finally found one. He congratulated himself and figured that at that rate, he could find a few nests each month. Three months and 250 miles later, Miranda had failed to locate any more nests. He needed help. He began putting up posters offering a $100 reward for anyone who found one. His search led him to Brazil nut collectors, who rove the forest in search of fallen nuts, the basis of a profitable, sustainable industry. "I realized there were people doing transects in the bush for free all the time," he says. He starting reaching out to Brazil nut associations.

"I remember hearing about this crazy guy looking for harpy eagles in the Amazon," recalls Veridiana Vieira, president of the Brazil Nut Collector Association of the Green Valley Settlement. Before meeting Miranda, Vieira says, she had thought of harpy eagles only as chicken killers, although she'd never seen one herself. She especially liked the idea of contributing to science, so she signed up her association to take part in the project. Miranda taught the nut collectors how to do eagle call playbacks on their phones and how to spot signs of a nest on the forest floor. "Now everyone exchanges harpy eagle information by WhatsApp," Vieira says.

So far, her association and other groups of nut collectors have helped Miranda find 34 nests

FIERCE HUNTERS

With females weighing up to about 24 pounds, harpy eagles are the heaviest of all eagles. These apex predators of the rainforest's canopy layer can swoop through thick foliage and snatch prey as big as sloths and monkeys with their enormous talons.

Facial disk feathers (similar to those of owls) flare around the ears to sharpen hearing.

Short, broad wings help them navigate narrow spaces.

Knee

Ankle

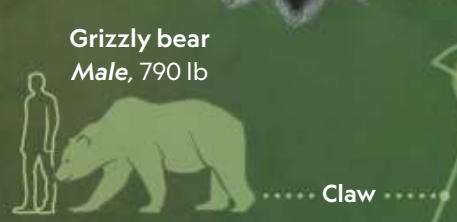
Tendon

Sloth
(14 lb max)

A long tail acts as a rudder for maneuverability.

Hunting large prey can be risky. Sloths and monkeys occasionally fight off—and even kill—harpy eagles attacking them.

Powerful legs act like battering rams during attacks. Foot tendons tighten, contracting talons around heavy prey before the bird takes wing.



Female, 24 lb max, twice as large as a male harpy eagle

A female harpy eagle's talon can be larger than a grizzly bear's claw. (Both shown actual size)

FERNANDO G. BAPTISTA AND CHRISTINA SHINTANI, NGM STAFF; MESA SCHUMACHER
SOURCES: EVERTON MIRANDA; IUCN

Ecotourism is already having a positive effect on harpy eagles, biologist Everton Miranda says, by showing landowners that "the forest is not an economically sterile place." He believes that the Amazon region where he works eventually could attract hundreds of visitors coming to view harpy nests each year. This would be a boon for the raptors and countless other species in the forest and for the people who live there.

across the state—a "remarkable and incredibly valuable and unusual" data set, says Watson, whose organization has compiled the only other comparable nest record, in Panama.

Miranda also launched a public relations campaign to educate people about harpy eagles and try to reduce the numbers killed purposefully. He saw photos of people holding up dead harpy eagles or their body parts during his interviews with 180 landowners and calculated that they'd shot at least 180 eagles in two years. More than 80 percent said they'd never seen such a giant bird and just wanted to get a closer look.

"In Portuguese, we have this expression, 'We need to see with the hands,' " Miranda says. "Many people told me they wanted to see the bird with their hands." Miranda was heartened, though, when many landowners also told him they regretted shooting a harpy eagle, especially after learning more about the threatened birds.

"Nowadays everyone realizes that harpy eagles are a positive thing for the region, so people don't kill them anymore," says Roberto Stofel, a former logger and hunter who works with Miranda as a professional tree climber. In two cases, a logger and a rancher even rescued harpy eagle chicks that otherwise would have been killed. Miranda, Stofel, and their colleagues rehabilitated and released them.

PREVENTING EAGLES from being shot is helpful, but the real challenge, Miranda says, is finding ways to make money off the forest that don't involve clearing enormous tracts. "We're burning

the world's most biodiverse forest to raise a few skinny cows," he says. "To stop deforestation, we need to find a smart way of integrating the Amazon with the global economy."

The good news, he adds, is that Brazilians can make money without felling trees. Collecting Brazil nuts and farming fish, for example, are more profitable and sustainable than cattle ranching, according to several scientific studies. Tourism could offer another viable alternative.

In December 2016 Miranda got in touch with Charles Munn, co-founder and owner of SouthWild, an ecotourism company based in Cuiabá, Brazil, and within a month, they had a contract in place. "A lot of scientists are purely interested in basic research, not in applying their findings toward searching for sustainable solutions," Munn says. "Everton is unusual in that he also really cares about creating green jobs and protecting nature."

Munn, who organizes high-end photo safaris across South America, has a track record of making conservation profitable. He was the first to bring tourists to see the now famous jaguars in Brazil's Pantanal region, the world's largest tropical wetlands. One study showed that jaguar tourism generated nearly seven million dollars in annual revenue for seven lodges throughout the Brazilian Pantanal. The ranchers who benefit from tourism no longer shoot jaguars—even if the cats occasionally kill their cattle.

"This is like wildlife venture capitalism," Munn says. "We try to figure out which things might work to actually leverage these animals to protect their habitat from us." As of July 2020, Miranda had recruited 35 landowners with harpy eagle nests on their properties to join the program. When the nests produce a chick, Munn's company hires local people to build 90-foot-high viewing towers for tourists to use. Landowners receive $20 a day for each visitor, and others in the community earn money as porters, drivers, and cooks. Munn issues a money-back guarantee that his guests will see a harpy eagle at eye level.

Miranda believes Mato Grosso eventually could attract about 700 people to view harpy eagle nests each year. That would be profitable for Munn's company—and a windfall for eagles.

Even at this early stage, tourism is having an effect, Miranda says, by convincing the landowners that "the forest is not an economically sterile place." Some are in it for more than just profit. "As important as the additional money is, I also like to be involved directly in preventing species extinction," says Cenomar Picouto, who has hosted tourists on his 60-acre ranch.

Miranda says he's committed to securing a future for harpy eagles and the biodiversity they represent. He plans to launch a predator institute next year in Alta Floresta dedicated to extending basic research and practical solutions.

"Conservation in the Amazon will only work if people who live here also own and drive conservation," Miranda says. "At some point, we'll realize that the Amazon is Brazil's greatest asset." □

Rachel Nuwer is the author of the book *Poached: Inside the Dark World of Wildlife Trafficking*. Photographer **Karine Aigner** focuses on the relationship between animals and humans. This is her first story for the magazine.

OUR TRAILS OUR LEGACY

National scenic paths take us to America's last wild places, but they're threatened by neglect, climate change, and crowding. It's up to us to preserve them.

BY **NICHOLAS KRISTOF**
PHOTOGRAPHS BY **ZACHARY KRAHMER**

The 2,650-mile Pacific Crest Trail (PCT) provides access to the Castle Crags Wilderness area in Northern California, where Micah Bettinger leads climbing groups up the granite eastern face of 5,400-foot Mount Hubris, known as the Cosmic Wall.

PREVIOUS PHOTO

Magdalena Balazova looks out over a valley near the PCT in Yosemite National Park, California. More hikers are using long-distance trails for recreation, but the paths often suffer from lack of maintenance.

My summer place is priceless: Not even Jeff Bezos or Bill Gates could buy it today.

It sits on the slopes of Mount Hood in Oregon, near the Pacific Crest Trail. It's at timberline, where stunted trees give way to delicate alpine meadows bursting with flowers. A glacier-fed creek serenades me as I sleep at night.

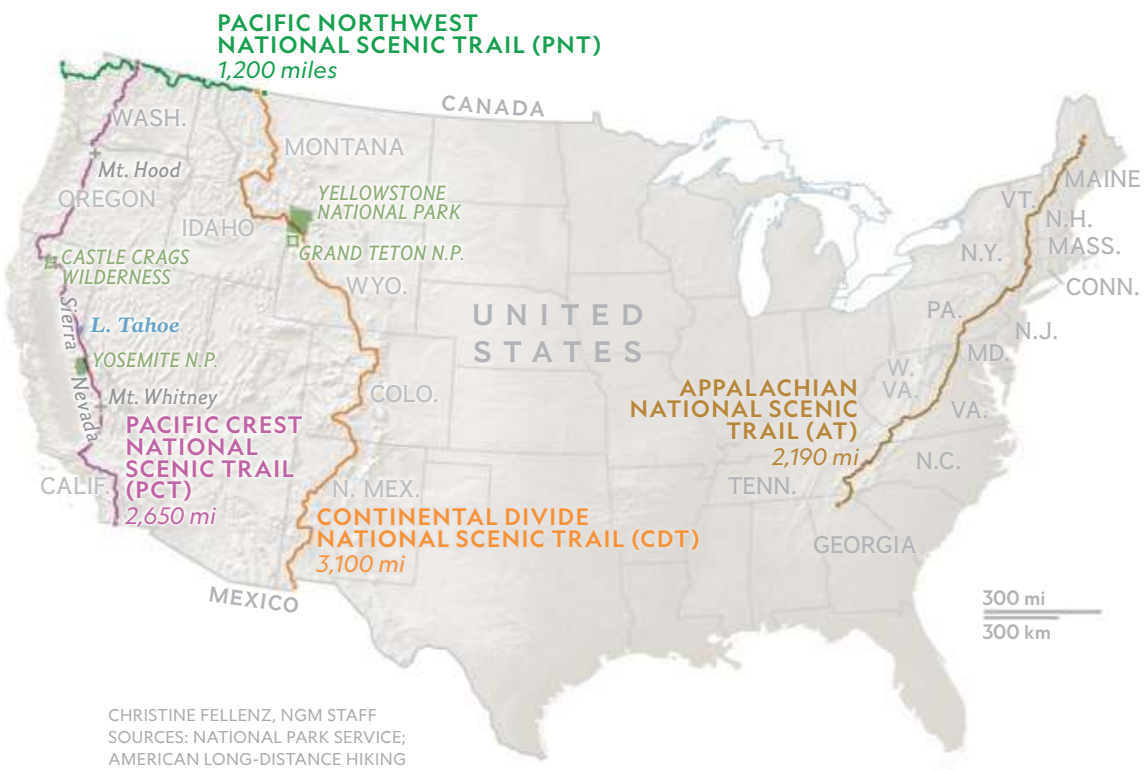
I've been visiting my summer place since I was 14. Most of the year it's covered in deep snow, but even in winter it reassures me from a distance. If I have trouble sleeping, I conjure the scene, and nature lulls me.

Fortunately it's in my family, and I hope my unborn grandchildren will one day play in the brook as well. Yet, while it's in my family, it's also in yours. It's my land and your land. It's public land, part of a wilderness called Paradise Park.

It lies near a trail built around Mount Hood in the 1930s during the depths of the Great Depression by the Civilian Conservation Corps. It was eventually stitched into the Pacific Crest Trail.

HIKING AMERICA

The combined length of the Pacific Crest, Continental Divide, and Appalachian National Scenic Trails is about 7,900 miles. More than 400 people have completed all three, an accomplishment known as the Triple Crown of Hiking.



CHRISTINE FELLENZ, NGM STAFF
SOURCES: NATIONAL PARK SERVICE; AMERICAN LONG-DISTANCE HIKING ASSOCIATION-WEST

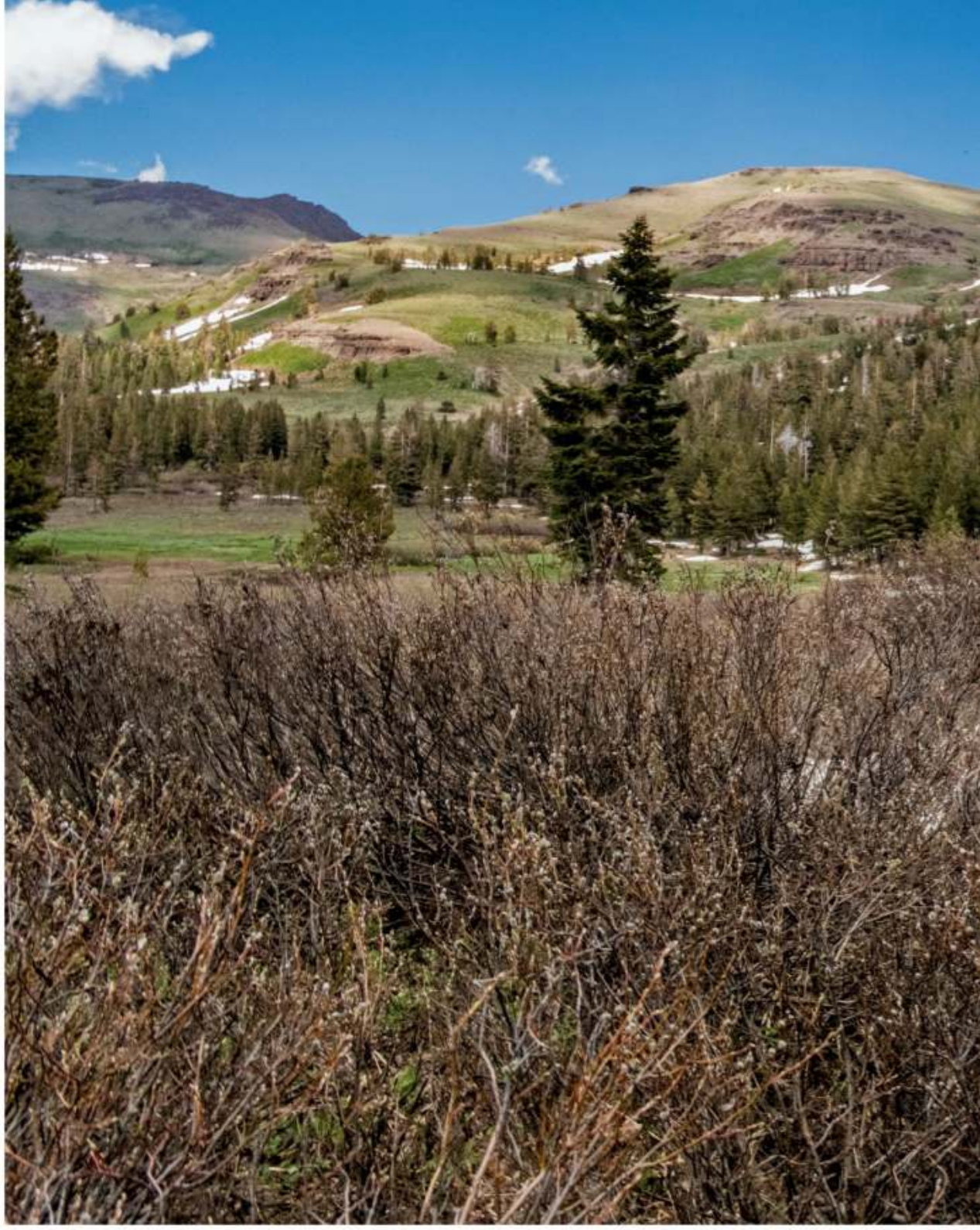
Even when we were a much poorer nation, we were able to allocate resources to make this wilderness accessible. Yet today, as one of the richest countries in the world, we find ourselves unable to maintain these trails properly.

Trails are in danger for interrelated reasons, including climate change, fire, and lack of financing. We not only have failed to protect our inheritance but it sometimes seems as if we're squandering it. "So many of them have disappeared," says Barney Scout Mann, arguably the dean of America's long-distance trails, as well as author of *Journeys North,* about his Pacific Crest Trail thru-hike. Mann, president of the board of the trails advocacy group Partnership for the National Trails System, has been hiking since the 1960s and recalls secondary trails that were never maintained and so returned to wilderness. "Trails are a choice," says Mann. "If we don't use them, they disappear."

I BECAME ACQUAINTED with backpacking when I was about six years old and my dad took my mom and me on the first of many hunting trips in pursuit of wild boar. The wild boar were never imperiled, but I was hooked on the wilderness.

Then, in 1970, a 120-pound teenager named Eric Ryback reported that he had hiked the

Jason Greene and canine companion Frannie carefully cross the Sandy River, in Oregon's Mount Hood Wilderness area. The PCT skirts the western slopes of the mountain, the state's tallest at 11,240 feet.



Balazova—whose trail nickname is "Sticks"—pushes through thick brush south of Lake Tahoe. Snow covered large parts of the trail last year even through June, so hikers had to find their way along streams and over water crossings, navigating with maps, compasses, and GPS-based cell phone apps.

entire Pacific Crest Trail, which runs from Mexico to Canada. I devoured a *National Geographic* story about the trail and about Ryback's journey, as well as the best-selling book that he wrote. I was a farm boy in rural Oregon, about two hours from the trail, and I wanted to be Ryback. The next year I used my berry-picking earnings to buy a $19.99 backpack and set out to hike the Pacific Crest Trail. I've not stopped hiking since.

Ryback helped launch the first wave of interest in America's long trails, and then Bill Bryson and especially Cheryl Strayed started second and third waves when their books appeared about the Appalachian and Pacific Crest Trails. People now come from all over the world to hike America's long trails.

For my own family, these trails have been a rich part of life. Some kids have summer camp, and some families have beach vacations; my family had trails. My wife and I discovered that while our three kids squabbled on road trips, hiking left them too exhausted to bicker. We packed our youngest, Caroline, along on her first backpacking trip when she was just one year old, and her passion for hiking has grown over the years. When she was 14, in 2012, she and I began to hike the whole Pacific Crest Trail, 200 or 300 miles at a time, finishing six years later.

We tangled with rattlesnakes and dehydration in the Southern California desert near the Mexican border, with altitude sickness and snow blindness in the California Sierra range, with mammoth snows that forced us to go off-trail in Oregon, and with torrential rains and freezing cold in northern Washington. Caroline is a plucky girl who never complains, so I knew

there was a problem one morning in Washington as we marched through an icy drizzle. "Dad," Caroline began, as if she were asking a purely academic question, "how do you know when you have hypothermia?"

A trail culture has emerged, with its own vocabulary and nomenclature. Hikers have trail names: I'm "Scribbler," because I'm a writer, while Caroline is "Tumbler," because she was a gymnast and still does handstands on any cliff edge appropriate for scaring her parents. "PUDs" is short for "pointless ups and downs," as when a trail sends exhausted hikers up over a hill rather than around it. And "trail angels" are people who show up to bring cold drinks or hot pizza where a road intersects the trail.

Trails offer an antidote to our postindustrial complacency and materialism. Spinoza, the great 17th-century Dutch philosopher, argued that nature and its laws constitute God, and you understand Spinoza perfectly with the view at sunset on a mountain pass. Trails are the cathedrals of the wild, leaving us both awed and humbled before a presence larger than ourselves.

That yearning for trails seemed magnified in a time of plague. For Americans cooped up indoors in the spring of 2020 because of the coronavirus, fearful for jobs and lives, the endless expanse of the outdoors was like a beacon for the soul—yet many parks were closed and thru-hikers were told to go home (not all obeyed). The virus perhaps reinforces the craving to find our own Walden Pond and gain perspective on a tumultuous world.

WHEN TUMBLER and I were discussing hypothermia in Washington, a woman named Heather Anderson was setting a record by finishing the entire Pacific Crest Trail in 60 days. That's an average of 44 miles a day over extraordinarily rugged terrain.

As a child, Anderson hated exercise. But then she heard about the Appalachian Trail and was enchanted.

"This concept that there was an actual footpath where you could walk thousands of miles, just really struck a chord," she says. "I didn't know anything about hiking."

Anderson eventually became the first woman to hike all three long trails within one year: the Appalachian Trail, 2,190 miles, running from Georgia to Maine; the Pacific Crest Trail, 2,650 miles; and the Continental Divide Trail, the 3,100-mile king of trails running down the spine of the Rockies.

If you're hiking north on the Continental Divide Trail and spit to your left, the molecules may end up in the Pacific Ocean. Spit to your right, and they may end up in the Atlantic Ocean. But if you spend too much time thinking about that, you might walk off a cliff.

The number of thru-hikers, those who complete a trail in one go, has soared. No one tracks exact figures, but trail monitors estimate that in the 1990s, about 150 people set out to thru-hike the Pacific Crest Trail each year; now, almost 5,000 do. Likewise, for the Appalachian Trail, the figure has risen in that period from perhaps 1,500 a year to 4,000, and the Continental Divide Trail has surged from an estimated 10 a year to about 500.

CLOCKWISE FROM TOP LEFT

Nellie Trenga-Schein, aka "Twiggy," and friends catch a ride after buying supplies in Bishop, California. While in town, thru-hikers will visit the post office, recharge batteries, do laundry, and complete other chores.

A "trail family" consisting of members from Canada, Sweden, Israel, France, and Germany share a meal in California's Sequoia National Park. Some of them had climbed Mount Whitney together the day before.

Sisters Alice "Masterbraider" Bandeian and Marguerite "Hop-Along" Bandeian celebrate at the northern terminus of the Pacific Crest Trail in the Pasayten Wilderness. The terminus is near the U.S.-Canada border in Washington State.

Keifer Edelmayer eats dinner alongside Chips Creek in Lassen National Forest in Northern California.


NORTHERN
TERMINUS
CANADA
TO
MEXICO

Thru-hikers draw attention and jealousy, but they make up far less than one percent of trail users. Most are day hikers, weekend warriors, or section hikers, and all are an evolving crowd. When I began distance hiking as a teenager, the trails were mostly a domain of white men—people like me. But women such as Anderson are now everywhere on the trails. Strayed's book *Wild* attracted throngs of young women—some, like Strayed, seeking to find themselves by losing themselves in the wilderness.

As Strayed told me: "I lost six toenails over the course of my 94-day hike on the Pacific Crest Trail, but I gained everything that matters."

Numbers of hikers have soared in part because technology and lighter gear have made the wilderness more accessible. To be sure, the 50-year-old *National Geographic* article about the Pacific Crest Trail made a similar observation, noting wonderingly that a "nylon tent added only 3½ pounds" to a pack's weight. To put that in perspective, for shelter I now use a Zpacks tarp that weighs 7.4 ounces. (I realize that in another 50 years, some *National Geographic* writer will boast that her tarp has helium pouches that make it weightless.)

IN A TIME of inequality, trails equalize us. Obviously it costs money to buy gear and food, but there are typically no access fees for backpackers. Car campers may pay, but hikers just spread out a groundsheet and a sleeping bag, and the spot is theirs; only a bear can pull rank.

Hikers likewise are economically diverse: Construction workers mingle with surgeons. There is no class divide on the trails, no wealth or poverty—just PUDs that humble us all.

However, there is a lack of racial and ethnic diversity. Typically there have been few Black and brown hikers, although their numbers are slowly increasing, partly through the efforts of nonprofits such as Outdoor Afro that are connecting African Americans to the outdoors.

Elsye Walker, the first African American to complete the big three trails, says she had been warned about white supremacists in Idaho but loved her hike through the state on the Continental Divide Trail.

"The people there were amazingly friendly," she recalls. Her trail experiences left her thinking that the mental geography that divides America into red and blue states misses something about goodwill that transcends politics.

"There were so many people who just randomly picked you up and took you into their houses and fed you," she says. "My love for America did grow."

The hiking community is particularly short of Native Americans, even though the trails cut through their ancestral lands.

"These lands were stolen from native peoples' ancestors," says Amanda Wheelock of the Continental Divide Trail Coalition. "Every single mile is ancestral homeland to at least one tribe. That's something that the National Trail System in general doesn't always do a great job of talking about and thinking about in our management decisions, and that's something that the CDT is working on—and we're really bad at. We're trying to get better."

Environmentalists should try harder, I believe, not just to protect wilderness but also to usher people into it, in nondestructive ways. Partly that's to make the hiking community more diverse, partly to ensure that young people reared on screens get the chance to be stung by a bee, and partly to ensure that there is a long-term constituency for the outdoors.

We need to build that constituency because, frankly, trails haven't done well on our watch. They're struggling.

Overall, trail length in America has continued to increase, despite the lost trails, but many are in disastrous shape, and the long-distance paths are sustained in part with volunteer labor. Some one million trail maintenance hours are donated each year to clear fallen trees and remove brush.

But this isn't enough. The Continental Divide Trail is still unfinished, with long sections of the route following roadways, and the same is true of the next major trail I plan to tackle: the Pacific Northwest Trail, which runs from Montana through Idaho and Washington State to the Pacific Ocean. Volunteers can clear a fallen tree, but they can't survey a route and build the trail.

The lack of maintenance that is perhaps most infuriating is the failure to maintain drainage channels at regular intervals. Without them, rain turns a trail into a creek.

Once in central Oregon, Tumbler and I were hiking up a steep creekside trail during a tremendous downpour and we couldn't tell whether it was the creek we were walking in or the trail: There were simply two creeks side by side. After such erosion, the trail becomes

rocky, so backpackers hike along the side of it. Soon multiple paths scar the wilderness.

Why aren't trails better maintained? How is it that Franklin Roosevelt's impoverished America could carve great trails from the wilderness and today's affluent America can't even manage basic upkeep?

"The Forest Service budgets were eaten up by firefighting," says Tom Vilsack, who, as President Barack Obama's secretary of agriculture, oversaw the Forest Service. While the Forest Service has a new national trail strategy, it has trouble extracting adequate funding from Congress, and fires inevitably swallow up resources. One very hopeful sign: Congress in 2020 embraced the Great American Outdoors Act, which would provide billions of dollars for public land projects. It's one of the most important pieces of legislation supporting public lands in decades.

The surge in fires is partly a consequence of climate change that has left forests drier. In addition, warming has empowered the bark beetle and allowed it to devastate coniferous forests from Alaska to Colorado. Anyone hiking the Pacific Crest or Continental Divide Trail will see huge expanses of forest that look like primeval woods unaffected by humans—except that they are brown and dead, another loss related to climate change. These dead forests become tinder.

The result is that fires are now a fact of trail life. As a young backpacker, I never thought about forest fires, but in the past dozen years I've encountered two forest fires close up. Another time, smoke was so bad that I wore a face mask while hiking.

There's plenty of blame to go around for the plight of the trails. Mining, logging, and ranching interests seek to monetize public lands, diminishing the wilderness experience. Political leaders haven't always shown the passion for protecting public lands that Teddy Roosevelt did. Climate change continues unimpeded.

Yet we hikers also have to look in the mirror, for all of us bear some responsibility. Most of us have been too busy hiking on trails to lobby adequately on their behalf. We've often been complacent about climate change. And backpackers and mountain bikers, instead of working together to preserve wilderness they all cherish, sometimes spend too much time feuding.

We also can't blame anyone else for the ugliest blights on our trails: toilet paper messes, especially near campsites. A backpacker's trowel for digging a cat hole weighs less than half an ounce and should be on every equipment list.

Elsye Walker, seen here on the Pacific Crest Trail in Oregon, is the first African American to complete all three major long-distance trails.

The author, aka "Scribbler," and his daughter, "Tumbler," pause along the PCT in Oregon.

ONE CAN ARGUE THAT our protected wildernesses are the real American exceptionalism. The world has many democracies, many countries have advanced technology, and some nations have longer life expectancy or higher per capita income. But no other major country has a network of long trails that can compete with America's.

The way to understand Russia may be to take the Trans-Siberian Railway across the endless steppe. To see Australia, fly. In Venice, hop into a gondola. But to appreciate America, take a hike. These great trails are an only-in-America story. The loyalty they inspire among their alumni is reflected in the way that much of the maintenance is done by volunteer trail crews.

Our wild places put us in our place. They are, as the saying goes, "America's best idea," and we must become better stewards so that our children's children's children can also enjoy the opportunities to be savaged by mosquitoes or frightened by rattlesnakes—and be awestruck by the raw majesty of our natural world. ▯

Nicholas Kristof is a best-selling author and a Pulitzer Prize–winning columnist for the *New York Times*. **Zachary Krahmer** grew up in Oregon. This is his first feature for *National Geographic*. Additional reporting was done by **Stephanie Pearson.**

MUSTAFA ZORLU; KRISTOF FAMILY PHOTO

INSTAGRAM

NICHOLE SOBECKI

FROM OUR PHOTOGRAPHERS

WHO

A Kenya-based photographer who seeks to capture humanity's fraught and intimate connections to the natural world

WHERE

A village outside of Caynabo, Somaliland, an autonomous region within Somalia

WHAT

A Hasselblad 501CM camera and a Zeiss Planar 80mm lens

Sobecki has worked for nearly a decade in East Africa, where nations are burdened by conflict, the climate crisis—and now, COVID-19. Despite the challenges, she says, the people in Somalia are known for a wicked sense of humor. Consider Ahmed Abdi Omar, 17, and a porcupine caught invading his fields. In Sobecki's photo Omar has a rope leash on the captured pest (which is not an endangered species). Sobecki overheard villagers chuckling "that the porcupine would be dinner that night." She didn't stick around for the punch line.

This page showcases images from National Geographic's Instagram accounts. We're the most popular brand on Instagram, with more than 200 million followers; join them at **instagram.com/natgeo.**

Subscriptions For subscriptions or changes of address, contact Customer Service at *ngmservice.com* or call 1-800-647-5463. Outside the U.S. or Canada call +1-515-237-3674.

NATIONAL GEOGRAPHIC (ISSN 0027-9358) PUBLISHED MONTHLY BY NATIONAL GEOGRAPHIC PARTNERS, LLC, 1145 17TH ST. NW, WASHINGTON, DC 20036. $39 PER YEAR FOR U.S. DELIVERY, $44.00 TO CANADA, $51.00 TO INTERNATIONAL ADDRESSES. SINGLE ISSUE: $8.00 U.S. DELIVERY, $10.00 CANADA, $15.00 INTERNATIONAL. (ALL PRICES IN U.S. FUNDS; INCLUDES SHIPPING AND HANDLING.) PERIODICALS POSTAGE PAID AT WASHINGTON, DC, AND ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, PO BOX 37545, BOONE, IA 50037. IN CANADA, AGREEMENT NUMBER 1000010298, RETURN UNDELIVERABLE ADDRESSES TO NATIONAL GEOGRAPHIC, PO BOX 819 STN MAIN, MARKHAM, ONTARIO L3P 9Z9. UNITED KINGDOM NEWSSTAND PRICE £6.99. REPR. EN FRANCE: EMD FRANCE SA, BP 1029, 59011 LILLE CEDEX; TEL. 320.300.302; CPPAP 0720U89037; DIRECTEUR PUBLICATION: D. TASSINARI. DIR. RESP. ITALY: RAPP IMD SRL, VIA G. DA VELATE 11, 20162 MILANO; AUT. TRIB. MI 258 26/5/84 POSTE ITALIANE SPA; SPED. ABB. POST. DL 353/2003 (CONV L.27/02/2004 N.46) ART 1 C. 1 DCB MILANO STAMPA. QUAD/GRAPHICS, MARTINSBURG, WV 25401. SUBSCRIBERS: IF THE POSTAL SERVICE ALERTS US THAT YOUR MAGAZINE IS UNDELIVERABLE, WE HAVE NO FURTHER OBLIGATION UNLESS WE RECEIVE A CORRECTED ADDRESS WITHIN TWO YEARS.

Brew Your Bundle

GEICO can make it easy to save when you bundle your auto and home insurance through the GEICO Insurance Agency. No recipe needed. Visit geico.com and watch your savings bubble. **Happy GEICOween!**

GEICO

geico.com | Local Agent
1-800-947-AUTO

Black-footed Rock Wallaby *(Petrogale lateralis)*

Size: Head and body length, 45 - 52 cm (17.7 - 20.5 inches); tail, 44 - 61 cm (17.3 - 24 inches) **Weight:** Up to 6 kg (13.2 lbs) **Habitat:** Steep, rugged, rocky areas **Surviving number:** Estimated at 10,000 - 12,000

Photographed by Fred Olivier

WILDLIFE AS CANON SEES IT

Beat the heat. The black-footed rock wallaby does just that, finding refuges that shield it from the baking sun during the day and emerging in the relative cool of dusk to feed on grasses, herbs and flowering plants. As long as it stays out of the sun, the wallaby doesn't require water. But it does need food and shelter, both of which are getting harder and harder to come by due to habitat loss and competition from introduced herbivores. Predation by foxes and feral cats is also turning up the heat.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.

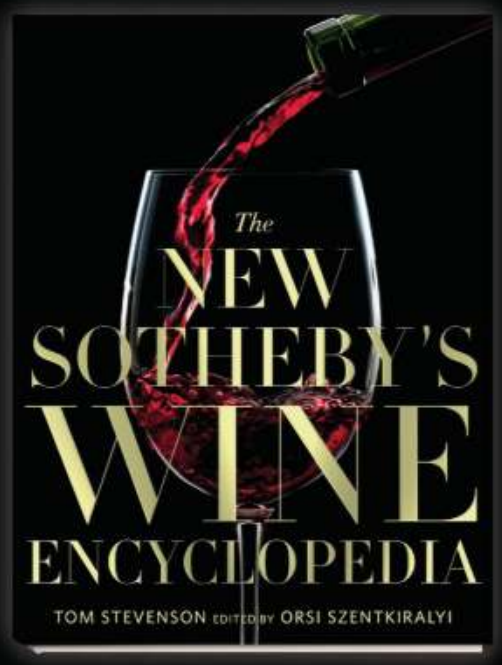
EOS System

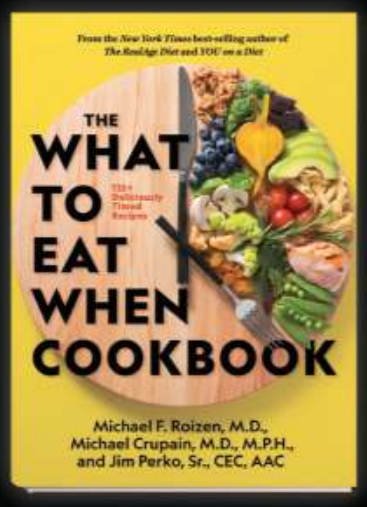
Canon

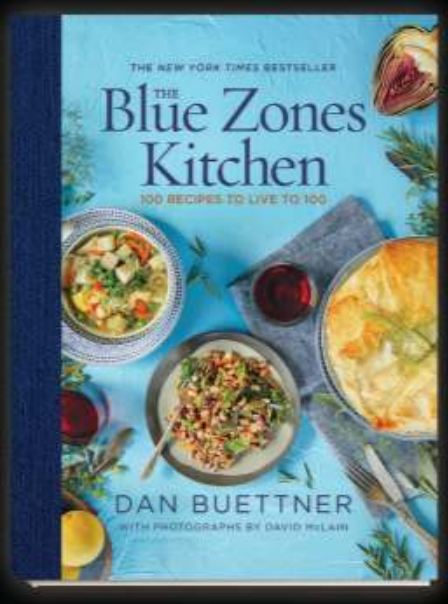
global.canon

MUST-HAVE BOOKS

FOR FOOD AND WINE LOVERS







AVAILABLE WHEREVER BOOKS ARE SOLD

NatGeoBooks @NatGeoBooks

NATIONAL GEOGRAPHIC